COMMONWEALTH OF AUSTRALIA
COUNCIL OF SCIENTIFIC &
INDUSTRIAL RESEARCH-1945
By G.Lightfoot

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(3) entomology
(4) australian scientific and industrial research
(5) animal health
(6) soil (7) forest products
(8) aeronautics (9) industrial chemistry

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COMMONWEALTH OF AUSTRALIA

COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

C.S.I.R.—1945

BY

G. LIGHTFOOT, M.A.

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MAP

SHOWING LOCATION OF

LABORATORIES AND PRINCIPAL FIELD STATIONS

OF

C S I R

Key to Map Showing Location of Laboratories and Principal Field Stations of C.S.I.R.

NEW SOUTH WALES.

1. *Sydney.*—(*a*) F. D. McMaster Animal Health Laboratory, University; (*b*) National Standards Laboratory, University; (*c*) Radiophysics Laboratory, University; (*d*) Radio Research Board, University; (*e*) Food Preservation and Transport Laboratories, Homebush; (*f*) Fisheries Laboratory, Cronulla.

2. *Armidale.*—University College (Parasitological Investigations).

3. *Badgery's Creek.*—F. D. McMaster Field Station (Animal Health).

4. *Barooga.*—Field Station (Sheep).

5. *Griffith.*—Irrigation Research Station.

6. *Young.*—Field Station (Animal Health and Pasture Improvement).

VICTORIA.

7. *Melbourne.* — (*a*) Head Office, East Melbourne (Administration); (*b*) Forest Products Laboratory, South Melbourne; (*c*) Animal Health Laboratory, Parkville; (*d*) Aeronautical Laboratory, Fishermen's Bend; (*e*) Industrial Chemistry Laboratory, Fishermen's Bend; (*f*) Dairy Research Section, Fishermen's Bend; (*g*) Lubricants and Bearings Section, University; (*h*) Radiophysics Sub-laboratory, University; (*i*) Mineragraphic Investigations, University; (*j*) Ore-dressing Investigations, University; (*k*) Fisheries Investigations, University; (*l*) Wheat Infestation Investigations, University; (*m*) Foundry Sands Investigations, Melbourne Technical College; (*n*) Field Station (Animal Health), Werribee.

8. *Merbein.*—Irrigation Research Station.

9. *Tooradin.*—Field Station (Cattle).

10. *Woorinen.*—Viticultural Field Station.

QUEENSLAND.

11. *Brisbane.* — (*a*) Food Preservation Research Sub-laboratory, Cannon Hill; (*b*) Fisheries Investigations, University; (*c*) Radio Research, University; (*d*) Agrostological Investigations, University; (*e*) Field Station (Drug Plant Investigations), Nambour; (*f*) Field Station (Cattle Tick Investigations), Yeerongpilly.

QUEENSLAND—*continued.*

12. *Anchorfield.*—Field Station (Pastures Investigations.

13. *Cunnamulla.*—" Gilruth Plains ", Sheep Station.

14. *Lawes.*—Field Station (Plant Introduction, Plant Genetics, and Noxious Weeds Investigations).

15. *Rockhampton.*—Field Station (Plant Introduction).

16. *Stanthorpe.* — Field Station (Apple Stocks and Scions).

SOUTH AUSTRALIA.

17. *Adelaide.* — (*a*) Animal Nutrition Laboratory, University; (*b*) Soils Laboratory, Waite Institute, Glen Osmond; (*c*) Mineral Deficiencies of Pastures Investigations, Waite Institute, Glen Osmond; (*d*) Ore-dressing Investigations, South Australian School of Mines; (*e*) Section of Mathematical Statistics, University.

18. *Robe.*—Field Station (Animal Nutrition).

WESTERN AUSTRALIA.

19. *Perth.*—(*a*) Agrostological Investigations, University; (*b*) Animal Health Investigations, University; (*c*) Soils Investigations, University; (*d*) Fisheries Investigations, University.

20. *Kalgoorlie.*—Ore-dressing Investigations.

TASMANIA.

21. *Hobart.*—(*a*) Fisheries Investigations; (*b*) Soils Investigations; (*c*) Laboratory and Field Station (Storage Disorders of Apples, Fruit Processing), Huonville.

AUSTRALIAN CAPITAL TERRITORY.

22. *Canberra.*—(*a*) Plant Industry Laboratories and Field Station; (*b*) Economic Entomology Laboratories and Insectaries; (*c*) Experimental Farm, Dickson (Plant Introduction, Plant Genetics, and Pasture Improvement Investigations).

FOREWORD.

Each year the Council for Scientific and Industrial Research publishes an Annual Report giving a comprehensive account of its work. These reports, however, are technical in character and furnish particulars of the various investigations in progress ; they do not include information regarding investigations completed in past years. Their circulation is limited mainly to Government Departments, Universities, scientific institutions, libraries, &c., and they are used largely for reference purposes by persons desiring to obtain information regarding investigations which are being conducted by the Council into particular problems or in different branches of science and industry.

As Minister in Charge of Scientific and Industrial Research, I have had the opportunity of informing myself generally of the important national work in which the Council is engaged, and I have been impressed by the wide range of the problems investigated and by the successful results achieved. No doubt there are many members of the general public who have knowledge of particular investigations which the Council has conducted and in which they are specially interested, but there are probably few who have had the opportunity of appreciating the full scope of the Council's activities or of realizing what has been accomplished. It is, therefore, desirable that a review of the Council's work should be made available, expressed as far as practicable in non-technical terms.

The war years have shown not only that Australia can fully pull its weight in the field of scientific effort, but also that we are able to transfer the experimental laboratory results into industrial production. What can be accomplished in war can be achieved in times of peace.

No one who reads the pages which follow can fail to be convinced of the great value of the Council's work. When peace comes, there must be no relaxation of our effort to apply science to industry. As the burden of work on war-time problems is relieved C.S.I.R. will be able to give increasing attention to scientific problems concerned with post-war reconstruction and development ; the assistance it can render in that direction will be of major importance to the future welfare of the Commonwealth.

J. J. DEDMAN,
Minister in Charge of Scientific and Industrial Research.

I.—ESTABLISHMENT AND DEVELOPMENT OF C.S.I.R.

Nearly twenty years have passed since the Commonwealth Government established C.S.I.R. for the purpose of carrying out scientific research for the promotion of the primary and secondary industries of Australia and, as will be seen later, the Council has an imposing record of achievement to its credit.

The constitution and functions of the Council are defined by the *Science and Industry Research Act* 1920-39. The Council itself consists of three members* nominated by the Commonwealth Government (one of whom is Chairman), the Chairmen of six State Committees, and other members co-opted by reason of their scientific knowledge. The Commonwealth Government nominees form an Executive Committee, which exercises all the powers and functions of the full Council in the intervals between its meetings.

In creating the Council, the Commonwealth Government followed the example of other countries, which recognized that national security and industrial development necessitate research often beyond the capacity of individual persons or enterprises. In Australia, the establishment of a body like the Council was of even greater importance than in most other countries owing to the relatively backward state of industrial development, the need for building up industries based on the utilization of Australian raw materials and thus opening up new avenues of employment, and the special nature of many problems with which Australia's agricultural and pastoral industries were confronted.

The activities of C.S.I.R. have necessitated a widespread and adaptable organization. Undesirable centralization has been avoided mainly in two ways. In the first place the policy has been followed of establishing laboratories in different places in the Commonwealth wherever the necessary facilities, contacts and other suitable conditions could best be found. Secondly, a State Committee, widely representative of scientific and industrial interests, has been established in each of the six States. These Committees advise the Council on general matters and on particular questions of investigation and research.

Extension of Activities.

For about twelve years after its establishment, the work of C.S.I.R. was devoted mainly to the solution of problems affecting the agricultural and pastoral industries. Unlike manufacturing concerns, which can often employ their own scientific staffs, the farmer and the pastoralist are dependent on outside help for the solution of their problems which require research. It was a recognition of the greater need of the primary producer which directed the Council's early policy. However, in 1937, the Commonwealth Government decided to extend the activities of C.S.I.R. so as to provide assistance to secondary industries, and the Council proceeded to establish several laboratories for work in that field ; it was thus in the fortunate position of being able to render to these industries assistance of vital importance almost immediately after the outbreak of war. In fact, the remarkable technological advances and developments in secondary industrial production during the war would to a large extent have

* A Bill before Parliament provides for the number to be increased to five.

been impossible had it not been for the assistance rendered by scientific research, and this may well serve as a forceful illustration of what may be accomplished in times of peace.

For the purpose of carrying out its research work the Council has established a number of Divisions and Sections. The Divisions, of which there are now fourteen, comprise the major establishments for which special laboratory buildings have been erected and equipped; the Sections generally include establishments which have not reached a stage of development, so far as the scope and magnitude of their operations are concerned, to justify their designation as Divisions. As the Council's investigations extend on a Commonwealth-wide basis and as many of the investigations which are being conducted—particularly those concerned with problems affecting the agricultural and pastoral industries, necessitate experimental work in the field, a number of field stations have been established in various parts of Australia.

The Divisions which have been established are as follow:—

(1) Plant Industry, with main laboratories at Canberra and field stations.
(2) Economic Entomology, also with main laboratories at Canberra and field stations.
(3) Animal Health and Production, with main laboratories in Melbourne and Sydney and field stations.
(4) Biochemistry and General Nutrition, with main laboratories at Adelaide and field stations.
(5) Soils, also with main laboratories at Adelaide and extensive operations in the field.
(6) Forest Products, with main laboratories in Melbourne and field experiments.
(7) Food Preservation and Transport, with main laboratories at Homebush, New South Wales, and a subsidiary laboratory in Brisbane.
(8) Fisheries, with main laboratories at Cronulla, New South Wales, and experimental work in coastal waters of Australia.
(9), (10), (11), National Standards Laboratory at Sydney—Divisions of Metrology, Physics, and Electrotechnology.
(12) Radiophysics Laboratory, with main laboratory at Sydney and subsidiary laboratory at Melbourne, and operational research groups.
(13) Aeronautics, with laboratories in Melbourne.
(14) Industrial Chemistry, with laboratories in Melbourne.

The following are the Sections:—

(1) Research Station, Murray Irrigation Area, Merbein, Victoria.
(2) Irrigation Research Station, Griffith, New South Wales.
(3) Lubricants and Bearings, Melbourne.
(4) Dairy Products, Melbourne.
(5) Mineragraphic Investigations, Melbourne.
(6) Ore-dressing Investigations, Melbourne, Adelaide, and Kalgoorlie.

In addition to its investigational work, the Council maintains a Scientific Liaison and Information Bureau which deals with a large number of enquiries covering a wide range of scientific and technical subjects. Since the outbreak of war the Council has established Scientific Research Liaison Offices in London

and Washington. There is also a Section of Mathematical Statistics, with headquarters at the University of Adelaide ; the main functions of this Section are (*a*) to provide the various Divisions and Sections of the Council with advice as to the proper planning of experimental work so as to obtain results which are of the highest degree of accuracy, (*b*) to assist the Divisions and Sections in the analysis of experimental data. and (*c*) to carry out research in statistical theory and its application to practical problems.

The Council's Head Office, with administrative and executive staff and central library, is in Melbourne. The funds for the Council are provided from two main sources, viz., from Commonwealth revenue by Parliamentary appropriation and from industry directly or indirectly by way of contributions and special grants. The fact that contributions and grants account for over one-eighth of the total annual expenditure indicates that C.S.I.R. has succeeded in a very large measure in gaining the confidence of the public.

War Problems. With the outbreak of war the Council at once considered the steps it should take to reorientate its work with a view to rendering assistance in as direct a way as possible to the war effort. The result has been that at the present time practically the whole of the work not only of the new secondary Divisions, but also of the older primary Divisions, is devoted to studies directly related to the country's war requirements. This has, of course, meant that nearly all the investigations on which these Divisions would normally have been engaged have been suspended. Though the primary Divisions have been diverted from their normal work and recent developments have been very largely in the direction of secondary industrial research this does not mean that the Council proposes in any way to abate its efforts in the direction of research into problems affecting primary industries. On the contrary, as will appear later, there is every reason why the post-war activities of the primary Divisions, as well as those of the secondary Divisions, should be extended.

Achievements and Post-war Developments. The activities of C.S.I.R. are now so comprehensive in their scope and so widely distributed that it is not an easy matter to present in a concise form an adequate picture of them. Moreover, a great deal of the work is not of a type which lends itself readily to explanation in non-technical terms. In the pages which follow, an attempt is made to give an account of the work of the Council with illustrative examples of the results which have been achieved, and to indicate briefly the directions in which assistance must be given by scientific research for the further utilization of our resources and the development of our industries, particularly in connection with post-war reconstruction. The account which is given of the Council's work must not, of course, be regarded as complete, for no survey of reasonable length could include all the investigations which have been and are being conducted.

With the cessation of hostilities Australia, in common with other countries, must pass through a most critical period in its economic development. The part which scientific research can play in such development and the influence it can exercise on national prosperity, on opening up new avenues of employment, and on maintaining a high standard of living, demand urgent and careful consideration. In the concluding pages, attention is accordingly directed to the need for providing for the adequate development of the work of C.S.I.R.

II.—PLANT INDUSTRY.

This Division has its central laboratories and experimental plant houses at Canberra. At Dickson, three miles distant, about 600 acres are available for field experiments. By no means all of the work of the Division is, however, conducted at Canberra. Its officers are located in various parts of the Commonwealth, where different investigations are in progress. Thus, two are permanently stationed in Tasmania working on storage problems of fruit; on plant introduction and agrostological problems there are two each in Queensland and Western Australia and one in New South Wales; there is one officer working on rootstocks for fruit trees in Queensland, and there are two in New South Wales engaged in other fruit problems. The Division operates in a field in which a considerable amount of experimental work has been and is being conducted by the State Departments of Agriculture. Therefore, in planning the programme of research it was necessary to avoid overlapping with the work of these Departments. Although the line between what should rightly belong to Commonwealth and State organizations in the field of plant research is not easily definable, in practice a very real spirit of co-operation between C.S.I.R. and the State Departments has been found to render a precise definition unnecessary. Broadly speaking, the Division concerns itself with problems affecting more than one State and with research of a more fundamental nature, the results of which may be expected to assist the work of officers of the State Departments.

Wide Scope of Investigations.

Prior to the war the Division was engaged in a number of investigations for the benefit and development of the agricultural and pastoral communities. One very important branch of work was in connection with the improvement of pastures, in respect to which the sheep, cattle and dairying industries in many areas in Australia were experiencing difficulties. The work was directed not only to the improvement of natural pastures in low rainfall areas, but also to improved pastures in higher rainfall areas by top-dressing, sowing, &c. Another important line of work was the breeding of plants to give higher yields and to be resistant to drought and disease, to produce new varieties, and to reduce variability and undesirable characters. Investigations were also conducted on the selection and development of high-yielding and otherwise desirable stocks and varieties so as to enable the fruit-grower to obtain trees most suitable for his particular conditions. The control of weed pests played an important part in the Division's programme, as also did investigations into diseases of plants, such as tomato wilt, leaf-spot in bananas, and diseases affecting tobacco plants, apples, pineapples, potatoes, fibre plants, peas, hops, and other fruits and vegetables. Special attention was paid to the introduction from other countries of varieties of plants, particularly of drought resistant pasture plants, likely to be suitable in Australia, and to investigations designed to improve the Australian tobacco crop.

Vegetables and Drug Plants. Following the outbreak of war much of the above work had to be abandoned or left partially in abeyance. Australia's dependence on other countries for supplies of vegetable seeds created a most serious situation which had to be met immediately owing to the greatly increased demand for vegetable foods. The Division took this matter up actively and as a result supplies of seed have been maintained successfully, despite many serious difficulties and setbacks. Again, anticipating a shortage of drugs from medicinal plants under war conditions, the problem of local production was investigated. Satisfactory materials have been found and techniques developed for the production of eight of these drugs. For the indispensable drugs atropine and hyoscine, an excellent source of supply was discovered in a native shrub and, indeed, Australia is now supplying the United Kingdom as well as her own needs. It is possible that the world supplies of hyoscine may come from this source after the war.

Plant and Fruit Diseases. Another direction in which the Division has achieved great success is the development of varieties of potatoes free from virus disease ; this promises to effect very great savings to potato growers, who frequently suffer losses of up to 25 per cent. or even more in their crops owing to the disease. An outstanding achievement is the control of blue-mould in tobacco seedlings, which was formerly the most serious factor in preventing the development of a successful tobacco-growing industry in Australia. Every likely method of controlling the disease by chemical sprays and specially constructed seed beds was exhaustively tested without success. Finally, a simple, practical and economic method of raising healthy seedlings was found, based on the discovery that the vapours of certain hydrocarbons, notably benzol and toluol effectively protected seedlings from disease. The Division has solved the problem of bitter-pit in apples, a storage disease which caused a loss of £100,000 a year to the apple export trade. It has discovered a simple method for the control of a disease known as water-blister in pineapples. It has introduced and acclimatized thousands of pasture and other plants, some of which show very great promise. Methods for the control of a number of serious weeds have been investigated and marked success has been achieved with some of them.

Northern Australian Problems. As to the future and the directions in which the Division should help in post-war reconstruction, in view of the profound importance of wool and meat in our national economy and of the deterioration which is taking place in pastures over many wide areas, investigations to improve our pastures must be developed. We have lost many lives and expended millions of pounds in defending Australia, particularly the northern parts of the Continent, and to justify that action we must now recognize that there is a great responsibility to see that industry in the north is developed to the fullest extent. That will mean large expenditure on research. Future developments must depend primarily on the extent to which pastures can be improved by the introduction and exploitation of pasture legumes and improved grasses, and by improved methods of animal husbandry. The developments which should follow would be at least comparable in magnitude to those which took place in temperate Australia after the war of 1914–18 ; they would be of the utmost significance in the post-war period, and would form a very substantial contribution towards increasing the population in the most vulnerable parts of the Commonwealth.

Irrigated Pastures. Similarly, too, with irrigated pastures, though the problem there is not so much bound up with the settlement of the country as with the proper and efficient use of land. In the post-war period there must be a rapid expansion of irrigation works and a substantial part of that expansion will lie in the use of partially irrigated properties on which pastures will be a major crop. The mistakes which have been made in the past must be avoided and this can be done only by the acquisition of basic information on the relationships between pasture plants, soil types, irrigation practices, and animal husbandry and nutrition.

After the war the control of weeds will be an even greater problem than previously because of the spread of certain of them under conditions of man-power shortage and the concentration of the work of the Division on immediate and urgent war production problems.

Tobacco. It is now sixteen years since C.S.I.R. became directly concerned with tobacco problems and, in the decade prior to the war, very substantial progress was made in improving quality and controlling diseases. If it is the policy of the Government to maintain a flourishing tobacco-growing industry in Australia, much further work in the way of research remains to be done. We should aim at the production of at least three-quarters of our requirements, i.e., 15,000,000 lb. of leaf annually. At the outbreak of war our production was about 6,000,000 lb.

Post-war Developments. The success which has attended the war-time investigations on drug plants exemplifies the developments which may be possible if the work is pursued effectively. We know relatively little about the medicinal and related values of our flora and a thorough survey should be made. Australia should never lapse into the dangerous condition of being dependent on foreign sources for the supply of vegetable seeds and, after the war, we should produce normal supplies of all essential kinds of the best possible varieties ; this will necessitate further research in the way of selection of varieties, control of diseases, and cultivation problems. Again, there is an important field of work in connection with the production of fibre plants, particularly flax, and investigations aimed at the control of disease and the acquisition of more precise knowledge regarding cultivation methods suited to Australian conditions should be pursued actively. The work already done on virus-free varieties of potatoes promises to be of very great value ; the development of stock free from virus must be maintained as an allied part of the potato improvement programme, which includes the selection and hybridization of suitable varieties. Virus diseases of many crops are tending to increase in range, complexity and importance, whilst soil-borne diseases of crops such as wheat, maize, and peas, form another group of problems for research. Plant breeding to obtain improved varieties and strains of crop plants will be as essential after the war as before, and with it the allied genetical studies designed to secure basic facts must be continued. We cannot rely on other countries to breed varieties and strains suited to our conditions ; our own types are essentially fitted for our environments, as has been shown with wheat, oats, maize, sugar-cane, subterranean clover, &c.

PLATE 1.

Upper.—During the war, opium poppies have been grown in Australia for the first time for the production of morphine, for which there was an urgent demand for our Armed Forces and civilian needs.

Lower.—Pyrethrum growing at the Division of Plant Industry's farm at Canberra. Japan, at one time, held a world monopoly of pyrethrum, used for the production of most fly sprays.

PLATE 2.

Upper.—Chrysolina gemellata beetles, shown here attacking the foliage of St. John's wort, are helping to control the weed, which has now spread from its original planting in a graveyard to cover vast areas of New South Wales and Victoria.

Lower.—Dengue fever mosquitoes being fed. A blood meal is required by the female before eggs can be laid. Similar cages in which two arms, bared to the elbows, can be exposed simultaneously are used in tests of mosquito repellants. These mosquitoes are vicious biters.

III.—ENTOMOLOGY.

Throughout the world insects are responsible for enormous losses to primary production ; and Australia, on the whole, probably suffers more than her fair share of these losses. Insect pests affect the Australian producer in a variety of ways. To name but a few : grasshopper swarms eat out crops and pastures ; blowflies cause severe losses amongst sheep and interfere with wool production ; the buffalo fly has for many years been a serious pest of the cattle industry in northern Australia and has recently spread to the east coast, where it constitutes a grave threat to the dairying industry ; the cattle tick, believed to have been introduced from Batavia in 1872, is a serious danger to our bovine herds and a grave menace to many industries ; the recently introduced cabbage butterfly has become very serious in many parts of Australia ; termites, commonly known as white ants, are notorious for the damage they cause to buildings.

In view of the great importance of controlling the various insect pests which levy so large a toll on our agricultural, pastoral and horticultural industries, the Council established a Division of Economic Entomology, with headquarters at Canberra, in 1927. The Division has been concerned mainly with problems which require long-range research and for the investigation of which the State Departments of Agriculture are inadequately equipped. Before a campaign against an insect enemy can be launched with any reasonable hope of success, the life history and habits of that particular species must be thoroughly investigated and understood. This involves careful research, which may often extend over a period of years. In a country such as Australia, whose insect fauna is but imperfectly known, a very considerable amount of preliminary fundamental work is usually necessary before what may be called the immediately practical aspects of a problem can be dealt with. The information furnished in the following paragraphs regarding achievements of the Division relates only to those problems in which results of immediate practical importance have been obtained, although substantial progress has been made in the elucidation of many others.

Sheep Blowfly.

Of all the entomological problems on which the Council has been engaged, that of the sheep blowfly is probably the most important, since it has been estimated that in a bad year it may cause a loss of £4,000,000 to the pastoral industry. It was also found to be one of the most complex and difficult. For many years investigations were conducted with a view to finding an effective method of control, such as by trapping, the introduction of parasites and predators from other countries, the poisoning of carcases on which the flies breed, and sprays and repellents. Some of these methods were partially effective, though the hopes which were entertained during earlier years of the possibility of biological control, i.e., the introduction of parasites and predators, had to be abandoned. Several new blowfly dressings have been evolved which are unusually effective. In recent years, as a result of co-operative work on this problem, means have been found by which a great part of the loss can be avoided in the future : this is referred to later in connection with the work of the Division of Animal Health and Production.

Cattle Tick. The cattle tick pest comprises two distinct affections of cattle, viz., tick infestation and tick fever. Very large numbers of cattle have died in Australia through tick infestation owing to loss of condition caused by the extraction of blood by the ticks and emaciation resulting from irritation. Tick fever, or red-water as it is often called, is a specific disease caused by a parasite transmitted by ticks. Thorough investigations have been made of the life cycle of the cattle tick for the purpose of obtaining fundamental knowledge necessary in connection with the conduct of eradication campaigns. In small scale tests, spectacular control of ticks has been obtained by the use of sprays of the synthetic preparation known as D.D.T., which readily kill ticks in stages which are resistant to the dips in common use.

Buffalo Fly. For many years the buffalo fly pest was investigated in North Australia, but it was not found possible to control it under the conditions there as the cattle range over large areas of country and are seldom handled. With the spread of the pest to the east coast of Queensland the character of the problem has changed completely for, particularly in dairy herds, the cattle are easily and frequently handled. It has now been shown that by the use of a special trap, through which cattle are made to pass, the number of buffalo flies attacking a herd can be reduced to a very low level. This method is particularly applicable to dairy herds. Moreover, it has been found possible to protect animals from attack by the fly for a period of about three weeks by the use of D.D.T. sprays.

Locusts. In organizing a comprehensive investigation of locusts or plague grasshoppers, Australia has fallen into line with other countries which for many years carried out intensive research on these pests. The Australian plague locust from time to time appears in vast numbers over areas of eastern Australia. Intensive investigations of the habits of this insect revealed the previously unsuspected fact that all major plagues have their origin in certain rather restricted districts. Making use of this knowledge, experiments are being conducted to find ways of preventing the development of plagues in these outbreak centres. This work is in an advanced stage and gives promise of providing means of preventing outbreaks instead of attempting to deal with them after they have become serious and widespread.

Termites. It is well known that termites or white ants cause great destruction to wooden structures ; though perhaps few people realize that it extends to the lead sheathing of telephone cables, that the nests or mounds of insects provide a problem in north Australian aerodromes, and that heavy infestation by grass-eating species may result in a serious reduction in the carrying capacity of pastures. Until recent years very little was known about the different species of Australian termites, but the Council's entomologists at Canberra have now obtained a great mass of systematic knowledge of the insects, in addition to collecting valuable data on their habits. This knowledge has been extremely useful not only in special termite investigations but in other ways. For example, when certain buildings were being erected in the Australian Capital Territory, the heavy termite infestation of the land caused some concern. This was dispelled when it was pointed out that the species were purely grass-eating

and did not attack timber. Perhaps the most important branch of the termite research is that concerned with testing the relative resistance of different timbers to attack and the efficacy of preservatives. As a result of the long series of tests which have been made, valuable information has been obtained and effective methods of preservation under certain conditions have been evolved. Aerodromes, and particularly emergency landing grounds, are often made dangerous by termites building mounds on them. Mounds broken up one day can be reconstructed overnight to a height of six to eight inches if the termites are not killed. A cheap and effective method of destroying these termite colonies by dusting with powdered white arsenic, costing approximately one-twentieth of a penny per mound for materials, has been evolved.

Wheat Pests. Wheat pests can readily be controlled in ordinary wheat silos, but under war-time conditions it was found necessary to store very large quantities of wheat as bag stacks, and in enormous piles of loose wheat in large structures referred to as wheat depots. Under these conditions, the ordinary methods of control could not be used. Investigations were conducted and methods evolved whereby control of both insect pests and mice could be obtained. The development of these methods has solved the major problems of the infestation of wheat stored under war-time conditions.

Wool Pests. During the war, enormous quantities of wool have had to be held in store in Australia. It was observed that the common clothes moth infested this wool and there was a probability of very great losses. Investigations were conducted and showed that the pest was confined to the outer two inches of the bales and effective control has been obtained by spraying the bales with special oil sprays.

Biological Control. Australia has provided one of the classic examples of the control of a plant pest by means of insect enemies. The success of the campaign against the prickly pear carried out by the Commonwealth Prickly Pear Board is well known. The effective clearance of pear-infested country in Queensland and New South Wales has opened up for agriculture and grazing millions of acres of previously useless land. The conquest of prickly pear is a telling advertisement and a very encouraging example of biological control, but, as with insect pests, this method cannot be regarded as a universal panacea which can be applied in the case of every noxious weed. Nevertheless, the control of both insect and weed pests by means of their natural enemies is the ideal method of dealing with these pests, for once an efficient natural enemy has been established, control is maintained automatically and indefinitely without further expense or effort. This method of control has had an important place in the investigations of the Division, but as the preliminary search for natural enemies, their introduction, establishment and ultimate spread inevitably take a long time, the results of the earlier work are only now becoming evident. The greenhouse white fly, a very troublesome pest, particularly on tomatoes, has been brought under effective control by the introduction of a parasite from the Oriental region. Insects introduced to combat the serious weeds lantana and St. John's wort are well established in most of the infested areas, and are already clearing the weeds from some areas. Parasites of the potato moth and cabbage butterfly, both very serious pests, have been established in the field, and parasites of various other pests are being handled under experimental conditions.

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Post-war Problems.

The work on insect pests so far undertaken by the Division has been confined to the investigation of some of the outstanding problems of economic importance. Several major problems, and a host of less urgent ones, have not been touched. Yet there are scores of pests which cause considerable annual losses greatly exceeding the relatively trivial cost of a few years' research into their control. Moreover, the war has revealed the great importance of certain pests which scarcely attracted attention previously. The following paragraphs give some idea of the kind of problems which should be tackled.

Practically every agricultural crop is subject to serious attack by one or more insect pests and for many of these no really satisfactory method of control is known. There is a very big field for work on vegetable pests, which are too numerous to mention, but many of them can be grouped under the headings of aphids, plant bugs, caterpillars, weevils, curl grubs, and eel worms.

Pastures in various parts of Australia are being seriously deteriorated by the ravages of insect pests. The red-legged earth mite, which is the most important pasture pest in Western Australia, was investigated for several years, and this work must be taken up again as soon as staff can be freed from immediate war problems. The underground grass grub, which causes much damage in some parts of eastern Australia and Tasmania, has also received some attention, but requires further investigation. The lucerne flea causes extensive damage to subterranean clover and lucerne. There are numerous other problems in this class calling for investigation.

A large part of the entomological work of the State Departments of Agriculture has been concerned with orchard pests, but still much remains to be done. The Division has already investigated the Oriental peach moth and citrus scales, but further work on both these pests is necessary. Other problems which call for particular attention are the codling moth, woolly aphis, light brown apple moth, numerous kinds of scale insects and aphids, and various species of boring insects.

The investigation of a number of serious pests of timber must be intensified as soon as possible and, in particular, the work must be extended to species occurring in northern Australia. There are large numbers of boring beetles and moths which damage both growing trees and timber, and, in addition, there are innumerable pests which attack growing trees.

As regards insect pests of humans, there is need for much further work on the control of disease-carrying insects. Moreover, there are many biting flies which, although they do not carry disease, are a serious nuisance to men in many areas, e.g., many species of mosquitoes, sand flies, and March flies. With a knowledge of the habits and life cycles of the various species, it should be possible to clear areas of some of these pests.

Virus diseases cause very serious damage to many crops and are commonly transmitted by insects. Work has already been carried out on insects which carry virus diseases of potatoes, tomatoes, and tobacco, but this should be intensified and extended to cover the insect transmission of virus diseases to other crops. Reference has already been made to the importance of biological control of insect and weed pests, and this work should be taken up again and intensified as soon as possible after the war.

The above are examples of specific problems requiring investigation, but there are certain general aspects of research which are of fundamental importance, and on which the solution of specific pest problems is largely dependent. There is urgent need for a thorough survey of the economic importance of the various insect pests in Australia. This is a primary requirement for the intelligent planning of future research. During recent years, new insecticides and new methods of application have appeared with almost bewildering frequency. As each pest problem has special features of its own, it is necessary to modify the insecticides or their methods of application in order to suit special conditions, and this demands much detailed laboratory and field work.

Although Australia's primary industries have already benefited greatly by the results of the Division's work, they still suffer enormous losses through the depredations of insect pests. It is obvious that there is a vast field of work awaiting attention. The control of even one insect pest might well repay very many times the total expenditure on the Division. The fight against insect enemies must be maintained, and the only effective and economical method of conducting the campaign is by careful scientific investigation.

IV.—ANIMAL HEALTH.

Since its earliest days C.S.I.R. has been engaged actively in the field of animal health and the work which it has carried out—in many cases in co-operation with State Departments of Agriculture and other existing institutions—has made possible the complete or partial control of many stock diseases which in the past have been responsible for heavy losses to pastoralists. It has been impracticable to obtain figures showing the total annual loss entailed through the diseases which are now controlled either wholly or partially, but there is no doubt that it must run into many millions of pounds. The Council's Division of Animal Health and Production has its main laboratories in Sydney and Melbourne and a number of field stations.

Pleuro-pneumonia.

One of the early problems to be tackled was contagious pleuro-pneumonia in cattle, a most serious scourge when it breaks out, particularly in the northern parts of the Continent, where irksome restrictions on the movements of stock involve the cattle industry in serious financial loss. The Council's work on this problem has received world-wide recognition, for it has been as important from a purely scientific point of view as it has been successful from a practical one. In the first place, the precise nature of the causal organism has been determined; the disease was produced experimentally for the first time in history and this enabled intensive study to be made; a technique for culturing the organism has been evolved, and from the pure cultures a vaccine has been developed which confers a high degree of immunity on the beasts inoculated with it. A great advantage is that the vaccine can be produced in large quantities and stored for long periods. Another major advance has resulted from these investigations; it is the development of a diagnostic test—the "complement-fixation" test—whereby the disease is diagnosed in "carriers", i.e., animals which, though showing no outward symptoms of pleuro-pneumonia, harbour the infection and can transmit it to other beasts. This test has been used very successfully by State Departments of Agriculture in the control of outbreaks of pleuro-pneumonia and has removed one of the most serious obstacles in the way of stamping out the disease from Australian herds. Supplies of the vaccine used for the tests have been sent at their request to Stock Departments in other countries where the disease occurs.

Tick Fever.

In previous pages relating to the work of the Division of Economic Entomology, reference was made to the serious losses of beef cattle in the north caused by the various tick-borne diseases known as tick fever or red-water. The organisms responsible are somewhat similar in nature to those causing malaria in man. Previous to the Council's undertaking research into red-water, one species of parasite was considered to be the sole cause of the disease. It was shown, however, that at least four different species occurred in Queensland, a fact which explained the frequently fatal failures in the generally effective process of inoculation. Pure strains have now been produced for inoculation and an effective and safe method of conferring immunity to the three pathogenic species of parasites has been evolved.

Zebu Cattle. An investigation of considerable importance in connection with the problem of settling a larger population in northern Australia relates to the use of half- and quarter-bred Zebu cattle—the cattle with the humped neck and long pendulous dewlap typical of India and other tropical countries. In America, herds of these cattle had been established in the vicinity of the Gulf of Mexico, and in 1933 the Council, in co-operation with several pastoralists, imported eighteen Zebu cattle and one cross-bred from America and settled them on properties of these pastoralists in Queensland. Systematic cross-breeding with British breeds was then undertaken. The chief difficulties in maintaining production at a high level with British breeds of cattle in northern Australia are that their body temperatures rise above normal levels in hot weather and they suffer badly from " tick-worry ". Zebus, however, suffer no discomfort in the heat and the pure-bred animals are completely tick resistant. Half-bred Zebus generally harbour a few ticks, but do not suffer from " tick-worry " ; the susceptibility of quarter-breds to ticks depends on whether they have inherited the Zebu or the British type coat. Zebu-cross cattle are also resistant to drought and possibly because they do not lose condition in a dry season, they reach a marketable size about a year earlier than British breeds. The carcases of cross-breds compare favorably with those of British breeds raised in the same area. British-bred cattle in the north do not provide maximum returns. If Zebu cross-bred cattle were generally used in the cattle country of the north, the result would be an annual increase of about 9,000 tons of beef worth £250,000. In addition, and resulting from cross-bred cattle being ready for market at least one year earlier than British-bred cattle of similar weight, there would be an increment of some 400,000 bullock-years, equivalent to an addition of 7,000 square miles of country capable of carrying twenty head of cattle to the mile.

Mastitis. Mastitis of milch cows is common in most, if not all, countries with temperate or sub-tropical climates and is the cause of great loss to the dairying industry of Australia. The disease has been studied by numerous workers in different countries over a period of many years, and is an infective disease due to one or other of several species of bacteria. It was not until comparatively recent years that bacteriological methods had advanced sufficiently far to permit differentiation between the many species of organisms concerned and the many types within the species. A thorough understanding of the facts is necessary before an efficient method of control can be evolved, and in 1935, C.S.I.R. initiated a long-term investigation into the problem. For that purpose an experimental herd was established and bacteriological studies have been made over several lactation periods. Studies have also been carried out in commercial herds. In addition, small experimental herds have been established to determine the effect of exposure to infection before the animal reaches a productive age. The life history of the several agents of infection and the general epidemiology of these have formed the main branches of the study. The main object has been to obtain accurate knowledge that will enable the development of methods of prevention of the disease. During the war attention has also been given to treatment of the disease in an effort to save wastage. In this way, a great mass of fundamental data has been collected and analysed, and valuable results of world-wide interest bearing on methods of control have been obtained. There are several forms of the disease and there is still much to be learned about

it. The investigations are being continued, but in the meantime, recommendations based on the knowledge gained have been made for the purpose of limiting the spread of the disease and alleviating the losses caused.

Peg-leg. Peg-leg of cattle is not due to the invasion of an organism, but is an example of the so-called deficiency diseases. It occurs mainly in the neighbourhood of Cloncurry and Charters Towers in north Queensland, in both of which districts it was found that there was a marked phosphate deficiency in the soil and pastures. The disorder is mainly evident in breeding animals and is aggravated in long dry seasons when the stock are forced on to dry herbage which is particularly deficient in that element. The first obvious step was to restore the phosphorus deficiency, but experiments showed that the trouble was not due solely to lack of phosphorus. Further experiments were accordingly conducted in order to determine the influence of trace elements—copper, zinc, nickel, cobalt and manganese—added to the phosphatic salt lick. However, the lick thus compounded proved to be unpalatable. Although a solution of the problem has not yet been found, the investigations are mentioned as they are illustrative of the complexity and time-consuming nature of the work on which the Division of Animal Health and Production is engaged.

Sheep Diseases. The Council has also obtained successful results from investigations aimed at the control of a number of diseases of sheep. For example, black disease was estimated to cause an annual loss of £1,000,000 in the eastern States, in which it was particularly prevalent. It was discovered that the disease is due to a bacillus which is stimulated into growth and invasion by the lesions due to the entry of young flukes into the liver tissues. The Council's investigators were successful in preparing a vaccine capable of protecting animals against the infecting organism. The use of this vaccine in conjunction with methods of liver-fluke eradication has formed the basis of the successful control of the disease now achieved.

Another example is the control of entero-toxaemia of sheep, which became possible after the cause had been determined by intensive investigation of the disease in Western Australia, where it was proving, as in the eastern States, a distinct limiting factor to the development of the sheep industry in the agricultural areas.

Mules Operation. After several years of study, the control of blowfly strike of the crutch of sheep has proved one of the most successful achievements. In the preliminary stages much knowledge was gained of the fly responsible for the strike, and concurrently the factors responsible for predisposition and susceptibility of sheep to strike were determined. This knowledge enabled the development of an idea first brought forward by a layman, Mr. J. H. W. Mules of South Australia. Finally a surgical procedure, the modified Mules operation, was evolved and this, combined with a longer tail stump, gave virtual control of crutch strike in sheep.

Foot-rot. Foot-rot in sheep is a serious problem over wide areas of Australian pastoral districts and occurs in some of our best sheep-raising country. It was probably introduced into Australia with some of the first importations of sheep. The losses occasioned by this disease vary from about

nil in very dry seasons to a large figure in wet seasons, when 50 per cent. or more of the animals in a flock may become infected. On some properties, it was necessary to abandon Merinos for a more resistant breed of sheep and even to give up sheep altogether for cattle. The disease may be much more prevalent on improved pastures than on natural pastures, so with the extension of pasture improvement the control of the disease becomes a matter of great importance. The views of previous investigators in many countries as to the cause of the disease were not confirmed by the Council's investigators, who found that the presence of a specific organism was necessary for its initiation. It was discovered that the organism could not live for more than a few days away from the sheep's foot and that the infection may survive during summer-time on the feet of some of the sheep but not in the soil. As a result of the knowledge thus acquired, it was shown that the disease could be eradicated completely from a flock by the simple procedure of systematic spelling of paddocks and treatment of feet before returning sheep to them. Once a property has been freed of the disease, foot-rot cannot recur as long as precautions are taken to prevent the introduction of diseased sheep.

Sheep Parasites. More particularly in the regions of better rainfall, sheep are affected by a number of different worm and fluke parasites and these are investigated at the Council's F. D. McMaster Laboratory in Sydney as the main centre. The investigations conducted there have been successful in discovering and improving methods of treatment. Usually drugs are employed for treatment and prevention of infection; but in certain cases a detailed knowledge of the life history of the species concerned has shown that control can be achieved by adjustments in stock management. One discovery of great importance was that solutions of copper sulphate effected a closure of what is known as the oesophageal groove in the sheep, and thus permitted drugs to pass straight to the fourth stomach, where most of the stomach-infesting parasites are found. This also permitted an increased proportion of these drugs to pass right through to the intestine. The determination of the value and of methods for the use of phenothiazine have resulted in a great advance in the control of intestinal parasites.

Other Diseases. Not all the investigations into animal health problems have been as successful as some of those described above. Two diseases in particular have proved very obstinate—haematuria in southern cattle and caseous lymphadenitis or cheesy glands in sheep. Although a large mass of useful and interesting information has been obtained regarding them, and some measure of control attained, much yet remains to be accomplished.

As a result of the Division's work other diseases in addition to those referred to above have been brought under complete or partial control. Thus, following an intensive investigation embracing experimental, bacteriological and pathological work, botulism in sheep in Western Australia—a disease associated with protein deficiency in the diet and manifested by the ingestion of rabbit carrion—has been brought under control by the use of a vaccine. The cause of another disease known as enzootic ataxia in lambs or Gingin disease—from the district in which it occurs in Western Australia—has been discovered and remedial measures evolved. Effective control measures have been discovered against the nodule

worm, which was responsible for very considerable losses in sheep in the summer rainfall areas of New South Wales and Queensland. A method for controlling a new species of external parasite of sheep has also been developed. Agrostological investigations in the higher and lower rainfall areas, particularly with a view to improving animal husbandry methods, have been conducted and valuable results have been obtained in some of the deficient coastal areas. These and other similar results of the Division's work have all contributed appreciably to the welfare and stability of Australia's animal industry.

Post-war Developments. The Division of Animal Health and Production had not reached maturity in its development before the war started in 1939. The animal industry, is, of course, no less important to Australia now than it was then, and the future calls for greater developments than in the past. There is need for vast improvement in our standards of animal production. In the sheep pastoral industry the control of bacterial and parasitic diseases has called for intensive research and very valuable progress has been made. Less attention has been given to production problems, though these are of extreme importance. If wool is to retain its position in the world's markets, its price must be kept sufficiently low to bring it into favorable competition with artificial fibres. Production costs must, therefore, be kept as low as possible. There are many problems to solve, not only in reducing actual expenditure on drought feeding, but also in preventing losses to stock by death from starvation. Further control of diseases would do much to prevent losses and to assist in lowering production costs. There is still much scientific work to be done with the object of bringing diseases under control and any post-war planning must give due consideration to that fact.

Plans have been prepared for a factual survey of wool production in the pastoral areas, and the results of this should help to reveal the effect of the environment on particular types of sheep and those types which have proved themselves most suitable for particular environments. Plans have also been prepared for a systematic study of sheep-breeding, and for the development of technical methods by which the production value of wool-growing sheep can be measured.

In both the beef cattle and the dairying industries there is need for much scientific work. Great improvements through breeding would follow the extension of the principle of the use of sires of proved value through progeny testing, in regard to the technique of which there is at present but little knowledge. This applies also to the sheep; the product wool is measured by weight of greasy and scoured wool and by several characters for which the methods of determination have not been placed on an exact or scientific basis. The problem is to improve both the weight of the clip and the character of the wool. There is much research to be conducted before progeny testing of sheep can be placed on a satisfactory basis.

Each branch of the animal industry has its special production and disease control problems. In all branches, breeding methods need overhaul; the production and conservation of fodder must be systematically planned and scientific feeding must replace present unscientific methods.

PLATE 3.

The quarter-bred Zebu bull above was depastured at Ingham, Queensland, with the Red Poll bull shown below. The Zebu bull has remained unaffected by ticks, while the Red Poll shows severe tick-worry.

V.—ANIMAL NUTRITION.

Soon after its establishment the Council received from many quarters evidence of the need for carefully planned investigations into such questions as the composition of pastures from the points of view of their protein, mineral and vitamin contents; the regeneration of depleted pastures; and the relations between growth of stock, nature of pasture and geological type of country. It was decided for the present to limit the work to the study of sheep. In planning it, the Council looked far ahead, as it was not expected to show major results for some years. The aim was to obtain information whereby sheep in various localities and climates of Australia might be so fed as to yield the best economic results. In 1927, the Council established a laboratory in Adelaide, now known as the Division of Biochemistry and General Nutrition, for the purpose of carrying out a scientific study of the nutritional physiology of the sheep and the influence of nutrition on wool production. The main reasons for this policy were (*a*) that the wool sheep economically is the most important of our domesticated animals; (*b*) that very little basic knowledge of its nutritional requirements was available; and (*c*) that it was clear that the efficiency of the wool-producing industry was seriously impaired by nutritional factors which were so little understood as to render simple solutions impossible. As basic knowledge was essential before the problems of the industry could be studied with reasonable hope of solution, the experimental programme was arranged so as to provide a foundation of exact scientific information before proceeding to practical application. This policy has proved to be well worth while.

Nutrition and Wool Production.

The chemical composition of wool was investigated and the findings have cleared up many problems connected with nutrition and wool production. Economic methods of overcoming the factors which limit the growth of wool followed directly, and these are being improved and extended as the results accrue from experimental studies. Investigations into the mineral requirements of the sheep led, on the one hand, to an exposure of the futility of costly practices which had been based on imperfect knowledge and, on the other hand, to the recognition of the importance of minor elements in sheep nutrition. The reasons underlying production of faulty wool and the failure of the usual procedures of pasture improvement have been ascertained and simple inexpensive procedures have been evolved to remedy the causes.

Coast Disease.

For example, cobalt has been determined as an essential mineral for sheep, and defects due to a deficiency of copper have been defined. The nature of the so-called coast disease has been ascertained and remedial measures applied with great success; this disease occurs in an area of some 2,000 square miles of high rainfall country in South Australia alone and extends

PLATE 4.

Sheep at the Animal Nutrition Laboratory in cages for testing various diets to increase wool production and improve its quality.

to Victoria, Western Australia and King Island, off the Tasmanian coast. The Council's investigators showed that the disease was associated with a deficiency in cobalt; rapid improvement followed the administration of a solution of mineral salts containing a very small quantity of that element. Whilst the major symptoms of coast disease were thus overcome, it soon became clear that another factor was involved and it was found that this was copper. This dual deficiency has now been remedied with most successful results. Another example of minor element deficiencies occurred in parts of South Australia, where the symptom was a marked change in the character of the wool. The normal crimped staple ran out to a straight lustrous growth; it was shown that the production of crimped wool invariably followed dosing the deficient animals with copper. As a result the value of the clips from copper-treated animals was increased by as much as 3s. per head.

Mineral Deficiencies.

The discovery by C.S.I.R. investigators that a minute quantity of cobalt is an essential dietary constituent for sheep and that the fodder produced in areas deficient in that element was incapable of providing it, opened a new chapter in the development of immense areas in southern Australia. The provision of this missing element at almost negligible cost restores the animals to normal health and productivity in a spectacular manner. Splendid healthy flocks and herds are now depastured continually on these areas.

The discovery led directly to the recognition that very widely dispersed areas were limited in their productivity by deficiencies of cobalt, zinc and copper in the soils. When small quantities of these elements are added to superphosphate used for top-dressing, splendid pastures may be established on deficient country, which hitherto had been considered practically useless. On other less deficient areas, the provision of copper to the flocks has resulted in an extraordinarily striking improvement in the quantity and quality of the wool clip. About three-fifths of the area of the part of South Australia having an annual rainfall of more than 12 inches is involved and a new era of agricultural development has come into being.

Food Requirements.

A detailed study of the food requirements of the sheep has established a sound and secure basis for the computation of the quantity of each of a wide variety of fodders necessary to support sheep, and has thus rendered available the knowledge essential for the formulation of long range policies for drought feeding and relief.

The fact that the soils of the greater part of Australia where sheep are depastured have a low phosphorus content led some years ago to the assumption that the productivity of our flocks is reduced by a lack of phosphorus in the pastures. This assumption resulted in the extensive use of phosphatic licks. As a result of tests which were carried out by C.S.I.R. grave doubts were, however, cast on the occurrence of phosphorus deficiency in sheep, and a series of properly controlled field experiments was conducted in order to study the effect of supplying extra phosphorus to flocks grazing on a variety of different types of country where the soils were known to be very low in phosphorus content. The results show that sheep thrive when they receive much less phosphorus than

was previously considered necessary, and was provided by many pastoralists at considerable expense. When the minimum requirements are fulfilled, further addition of phosphorus to the diet has no beneficial effect.

Pasture Management. A great deal of work has also been done on pastures, both natural and seeded, to determine the seasonal variations in nutritive value, the effect of different top dressings, and the importance of particular species of pasture plants.

The results of all these investigations have a most important bearing on problems of pasture management. They have elucidated many factors of far-reaching importance to Australia's pastoral industry and have shown ways and means for selecting sheep types which will more efficiently utilize the great tracts of our natural grasslands.

The type of experimental approach followed by the Division has more than amply been justified by the economic returns which have followed the widespread applications of the results to the pastoral industry. A large part of the work has been supported by generous financial grants from individual pastoralists and from pastoralists' organizations, which have recognized the necessity for this type of scientific attack on the problems of the wool-producing industry.

War Problems. Many novel problems of nutrition arose as a result of the war; the most important of these were associated with the victualling of our armed Forces. The Nutrition Division was asked by the Department of the Army to assist with nutritional problems, and has been actively engaged on research associated with these problems. Data upon which Service rations have been based have been furnished and many problems involving considerable experimental research have been solved. Investigations into problems concerned more directly with human nutrition are in progress in order to provide a basis for agricultural policies involving food production and food distribution during the war and the post-war periods.

Post-war Developments. It has already been pointed out that the future of wool as a textile fibre depends not a little on its cost of production; this, in turn, depends partly on our capacity to overcome the disabilities of nutritional conditions which impair the efficiency of the sheep as a wool producer. Consequently, the main activities of the Division should be devoted for some considerable period to experimental research concerned with nutritional problems of wool production.

While the basic knowledge of the nutritional physiology of other farm animals is very much more extensive than that of the sheep, there is a host of problems which are essentially the consequence of conditions peculiar to Australia and which demand investigation.

Privations which have supervened since the outbreak of war have led to an increased appreciation of the importance of human nutrition and to the realization of the significance of optimum nutrition for health and well-being. The expansion and reorientation of agriculture are necessary in order to produce foods which are nutritionally desirable. The Division has already extended its work to problems which are basic to the improvement of the nutritional status of our population. This work should be developed actively in the post-war period.

VI.—SOILS.

The national importance of the scientific appreciation of the land resources of Australia needs no emphasis. The intensification of farming under irrigation or by pasture development and the solution of problems of soil erosion and conservation all call for studies of the soil so as to prepare a solid foundation for proper land use, the efficient exploitation of existing resources, and the further investigations concerning crop and animal production which may be required. Work on soil problems was initiated by C.S.I.R. in 1927 in co-operation with the Waite Agricultural Research Institute of the University of Adelaide, and in 1930, a Soils Division was established with headquarters in a laboratory in the grounds of that Institute. The functions of the Division are to survey, classify and evaluate the soils of Australia and to carry out research into the chemical, physical and bacteriological problems concerned with soil fertility and agricultural production. Since 1927, soil surveys in different parts of Australia have been conducted continuously, with the result that up to date detailed surveys have been made of over 1,000,000 acres and reconnaissance surveys of nearly 2,000,000 acres. The Division works in close collaboration with the State Departments of Lands and Agriculture and the Water Conservation and Irrigation authorities: at the request of the Rural Reconstruction Commission of the Department of Post-War Reconstruction, it is collaborating in obtaining basic information necessary for the consideration of land settlement schemes.

Soil Maps. The results of the surveys are embodied in maps showing the distribution of different soil types in the areas surveyed, and these maps are, of course, of great value in determining the best method of utilizing and developing those areas. The basis for the definition of any given type is the soil profile, usually to a depth of 6 feet, soils having profiles uniformly similar belonging to the same type. It is clear that when the same standards are employed in different countries the identification of a soil type may mean that valuable information obtained from other countries is at once available to Australian workers. Moreover, it is only when soil types are based on the complete profile, taking into account their physical and chemical properties, that soil maps can be employed with confidence in determining a policy of land utilization and subdivision.

In defining for mapping purposes the limits of different soil types, the natural vegetation often provides a reliable guide. When practicable, therefore, during the course of a soil survey of a virgin area a botanical survey is conducted. In many areas, the ground work of the soil surveyors has been preceded and greatly facilitated by aerial surveys carried out in many cases by the Royal Australian Air Force. These have enabled use to be made of aerial photographs which have proved of immense value, especially in cases of unsurveyed and unmapped regions. Such photographs provide an ideal basis for a soil survey.

Murray River Settlements. The need for a thorough investigation of soil problems was most urgent and obvious in the irrigated lands of the Murray River Valley, and for some years the major part of the work of the Division was devoted to these areas. A proper understanding of soil conditions is obviously essential for the efficient use of irrigation water, and a lack of the necessary knowledge has led in the past to serious losses, mainly through the development of salting and seepage troubles. The investigations and surveys conducted by the Soils Division have revealed the origin and nature of these troubles, and have disclosed methods by which they have largely been overcome by the controlling authorities in the respective States. The whole of the horticultural settlements in the Murray Valley have been surveyed.

Detailed surveys such as have formed the basis of the Division's work in the irrigation areas are in many cases neither practicable nor necessary. This applies when extensive areas are to be surveyed and when the properties and potentialities of certain types of soil found over wide areas are being investigated. The following are some examples of the surveys which have been conducted :—

King Island. At the request of the Tasmanian Department of Agriculture a survey was made of King Island, off the Tasmanian coast, in order to provide a basis for the advisory and experimental work of its veterinary and agricultural officers. King Island is given over almost entirely to stock fattening and dairying, and was of particular interest because it presented a general problem of phosphate deficiency and a specific problem associated with the sand dunes of its western coast, where the only natural pastures of any value existed. This specific problem is that of coast disease, to which reference has already been made in connection with the work of the Division of Biochemistry and General Nutrition. The main soil types were identified, their properties determined, and their distributions shown on a soil map of the Island.

Tasmania. Tasmania itself has been the locus of a considerable amount of survey and investigational work by the Soils Division. At the outset, a soil map of the whole Island was prepared showing the boundaries of the major soil zones. This was followed up by an investigation of the apple-growing soils and by a soil survey of the orchard areas of the Huon Valley, and also by investigations of the soils of the pine plantations of the Tasmanian Forestry Department, and of the basaltic soils characteristic of the most fertile regions of the north coast. The most recent development in Tasmania is the survey of certain areas in the north-east and north-west selected for consideration in connection with post-war settlement schemes.

South Australia. An interesting piece of work carried out by the Soils Division was the survey of the bed of Lake Albert, at the mouth of the Murray River ; for the sampling had to be done from a launch through several feet of water and special apparatus had to be designed for the purpose. The object of the survey was to discover whether the soil of the lake bed was suitable for dry farming or production under irrigation. The results of the survey showed that the reclamation of the lake was not justifiable from either of these points of view, and the proposal was accordingly dropped. Thus, the expenditure of a very

modest sum of money, together with the application of recently developed methods of soil examination, prevented what might have proved to be a very costly mistake in land settlement.

At the request of the South Australian State Government, an area of about 12,000 acres close to the town of Loxton on the River Murray was examined as a potential irrigation settlement. The aim was to determine the nature of the soils for irrigation development and their probable suitability for various horticultural crops. From extensive experience on similar country, it was possible to classify the soils in conformity with other established settlements. A soil map was prepared showing the different types of soils and their grouping according to suitability for citrus, canning fruit, vines and vegetables. If the engineering evidence shows that water can be supplied economically, the efficient planning of the area and the subdivision of the farms will follow.

The survey in connection with soil erosion problems of an area of 400,000 acres in the wheat belt of South Australia has led to successful work by the Soil Conservator of the Department of Agriculture. Another survey designed to secure information regarding the correlation of pine-tree growth and soil type in an area of 350,000 acres in the lower south-east of South Australia has enabled both the State Government and private forestry companies effectively to extend the planting of softwoods. At the request of the New South Wales Water Conservation and Irrigation Commission, surveys of areas gazetted as irrigation districts have been conducted and the information thus obtained will greatly facilitate the proper planning and subdivision of the settlements and the efficient use of irrigation water.

Laboratory Work. Laboratory investigations constitute an important part of the Division's work. The examination of soils by both chemical and physical methods is of course necessary to a thorough understanding of conditions observed in the field. Problems of soil fertility have to be investigated, such as those associated with excess of salt in irrigation areas and with deficiencies in minor elements such as copper, zinc, and molybdenum in areas of high rainfall. The efficient use of irrigation water and the disposal of superfluous water by drainage both demand a thorough knowledge of the physical behaviour of the soil and of the principles governing the mutual relations between soil and water. More recently, the stability of the soil in relation to erosion and the maintenance of soil fertility have received attention and the concepts involved have been applied to the practical problems connected with soil stability in airfields.

Nitrogen-fixing Bacteria. Valuable work has been carried out in connection with the nitrogen-fixing bacteria which occur in the root nodules of leguminous plants, special attention being given to subterranean clover and lucerne. It is on these nodule-forming organisms that the power of such plants to increase the fertility of the soil so largely depends. Great variation was found to occur between the different strains of these bacteria. The effective strains have been isolated and are made available to the State Services responsible for the distribution of bacterial cultures to farmers.

War Problems. The Division has been able to render material assistance in certain directions in connection with the war effort. For example, important problems arose out of the decision to use soil-cement for the construction of aerodrome runways. A programme of investigation was undertaken and as a result, the Division was able to give advice regarding site selection, methods of construction, &c. Similar investigations on dust nuisance and soil stability were undertaken at the request of the R.A.A.F. The Division is assisting the Department of the Army with advice on soils from areas under consideration for the establishment of Army farms in the Northern Territory and New Guinea.

Post-war Developments. As regards post-war and reconstruction activities, it is most important that the Soils Division should be developed so as to enable it to carry out effectively and without undue delay the work desired by various Commonwealth and State authorities. The immediate aim is to survey all areas in Australia proposed for land settlement schemes unless they are already being investigated by the States. Many requests for soil survey work have been received by the Division, and on behalf of the Rural Reconstruction Commission and State authorities extensive programmes have already been prepared for work in New South Wales, South Australia, Western Australia, and Tasmania. It is anticipated that requests for similar services in Queensland will be forthcoming and that they may extend to northern Australia and New Guinea.

With its existing facilities and the funds available, it will be impossible for the Division to comply with these requests within a reasonable time. It is well known that after the 1914–18 war serious mistakes were made in the planning of certain land settlement schemes. In many cases these mistakes were due in no small measure to a lack of knowledge of the soils in the respective areas, and thus, to the absence of information on which effective planning and subdivision could be based.

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KEY TO SOIL TYPES

CURLWAA (Cs - Csl - Cl) ____

POMONA (Pcl - Pc) ____

WENTWORTH (Wl - Wcl - Wc) ____

TAPIO (Tsl - Tl) ____

YELTA (Yl) ____

SCALE

Chns. 5 4 3 2 1 0 5

Del Peter D. Hooper

PLATE 5.

Aerial photograph of approximately 150 acres of irrigated horticultural land in Curlwaa District adjoining the River Murray near Wentworth, New South Wales. The main plantings shown are oranges (square pattern) and vines (parallel lines). Light and bare patches may indicate missing vines or trees, salty condition of soil, or heavy-texture poor soils. Even growth of trees and vines indicates better soil type, absence of salt, or better management. The soil map of the same area on the opposite page shows how the changes in soil type correspond, in many places, with differences in vegetation. For instance, the heavy texture of Pomona clay indicates the poor and indifferent growth of citrus and vines in those patches. The areas of Curlwaa soil types indicate the better growth as seen in the photograph.

VII.—IRRIGATION SETTLEMENTS.

C.S.I.R. has two Irrigation Research Stations, one at Merbein on the Murray River in Victoria, the other at Griffith in the Murrumbidgee Irrigation Area, New South Wales. Both are situated in the midst of important irrigation settlements and maintain the closest touch with the settlers. In fact, the Merbein Station, established to carry out investigations into viticultural problems, was originally financed by the settlers themselves before it was taken over by C.S.I.R.; the Dried Fruits Control Board and the several fruit-packing companies in the Merbein–Mildura–Red Cliffs district and others, all contribute towards the cost of this work. The Griffith Station was established for research on citricultural problems and is supported financially by the New South Wales Water Conservation and Irrigation Commission.

Both stations are really more than research centres; they are places to which the growers go for advice on matters, large and small, connected with crops and irrigation. Moreover, full use is made by the State irrigation authorities of the knowledge gained from the stations' experiments. This has been reflected in marked improvement in irrigation practices, the initiation of communal drainage schemes, &c. All crop producers are faced with problems of disease, methods of cultivation, maintenance of yield, and the like; but in the irrigation settlements the range of problems is extended, so to speak, at both ends. On the one hand, the application of water to the soil has produced a number of unforeseen troubles, whilst on the other the crops grown usually require special handling and treatment after harvesting. Both Stations are concerned with every aspect of production under irrigation and, therefore, have had to undertake a wide field of investigations.

Research into soils and their behaviour under irrigation has been carried out both at Merbein and Griffith, in close co-operation with the Soils Division. Special attention has been paid to the movements of salts in the soil; for the accumulation of salts is one of the chief causes of reduced fertility and has in some cases led to whole blocks going out of production.

Merbein. The work of the Merbein Station has been directed mainly towards the solution of problems associated with the irrigation of Murray soils, the preservation of soil fertility under irrigation, the horticultural procedure necessary to give maximum returns, and the processing and preservation of the products. Its work extends to all irrigation settlements in the Murray Basin, from Mypolonga in South Australia, to Wakool in New South Wales and Kerang in Victoria. Investigations into vineyard practices—pruning, tipping,

PLATE 6.

Vegetable-growing in an irrigated area, with irrigation furrows following the contour of the land.

cincturing, &c., methods of cultivation, and the use of fertilizers—have been carried out continuously since the establishment of the Station. This directly practical work has been greatly assisted by the results of research of a more fundamental kind, involving a detailed study of the vines, the growth of their shoots and roots, development of the buds, and the seasonal movement of the foodstuffs within the plant.

Irrigation Waters. The ideal in applying irrigation water is to moisten the soil to a required depth without wastage. The duration of soakage required to do this varies with the soil type, the rate of application, the initial moisture in the soil, and the method of irrigation. As a result of field and laboratory measurements, procedures have been defined which closely approach the minimum efficient quantity of water required to wet the soil to field capacity. The methods evolved are now generally applied to the practical irrigation of commercial holdings, with the result not only that there has been a substantial improvement in vine growth and production, but also that very considerable quantities of water have been saved.

Water-logging. Until recent years the general conception, supported by universal experience through the ages, was that irrigation community settlements had a limited life. With continued irrigation, large tracts of land become wholly or partially unproductive, due to soil changes, including water-logging and the rise of injurious salts. Investigations covering the occurrence of injurious salts in virgin lands and the translocation resulting from irrigation have been carried out at the Merbein Station and the necessary remedial measures have been defined. Recommendations covering the depth and spacing of agricultural drains for reclamation and for soil preservation have been made and have been adopted over large areas.

Dried Vine Fruits. Before the war the greater part of the pack of dried vine fruits produced in Australia was exported overseas, Great Britain being by far the most important market. There it had to compete with fruit grown in the United States of America and the Near East, and naturally it could do so successfully only if a high standard of quality and appearance were maintained. In the early years, the Australian product was definitely unsuitable for the overseas market, owing to the dip used by the growers imparting to the raisins and sultanas too dark a colour. The Merbein Station accordingly set itself to evolve a dip which would give to the product a uniform light colour and, in addition, would permit more rapid drying. This object was achieved, with the result that before the war, when export ceased, the Australian product was able to compete successfully with the products from other countries. Trade returns showed an increased value for fruit treated with the improved dip as compared with former methods and this represented a very substantial gain to the industry. Moreover, the production per acre in the old established areas—that is, exclusive of new plantings—has been more than doubled. New methods devised at the Station and incorporated in routine practice cover the dipping, drying, field and factory processing, packing and storage of dried vine fruits and stone fruits.

Insect Pests. Formerly the infestation of dried fruits by insects presented a serious problem and adversely affected both the extent and price of sales overseas. Structural alterations and the adoption of hygienic conditions in packing and store-houses were partially successful, but the trouble was not wholly overcome until investigations at the Station showed that the injection of a small quantity of a fumigant, ethyl formate, into a box of dried fruit killed the insects in all stages. The adoption of this method has resulted in efficient control.

War Problems. Special wartime activities of the Merbein Station include readjustments—owing to shortage or cessation of supplies—in the application of fertilizers and processing methods. Other war activities include the production of drug plants on a large scale ; dust prevention on R.A.A.F. aerodromes ; and investigations in connection with the expansion of vegetable production to new areas and the introduction of new and improved varieties and strains of vegetables.

Griffith. The citricultural investigations conducted at Griffith include the study of the nutrition of citrus trees and experiments in cultivation practice and the use of different fertilizers. The green-manuring investigations have been of particular interest. It was found that trees in the plots under summer-growing green manure crops, such as cowpeas and lucerne, grew more slowly than those on clean cultivated ground and yielded less fruit : but when a winter-growing legume, such as the tickbean, is grown as a green manure the growth of the trees is significantly increased. As a result of this work, green-manuring with tickbeans has become an accepted practice in well-managed orchards throughout the Murrumbidgee area.

Fertilizer Requirements. Experiments at the Griffith Station have defined for the first time in Australia the fertilizer requirements of orchard trees. Contrary to what was previously the popular belief, it was found that citrus trees require considerable amounts of nitrogenous fertilizers, but do not require any added phosphates. These investigations have had a profound effect on the use of fertilizers in the area.

Alternate Crops. Valencia oranges share with certain apple varieties the objectionable habit of bearing, in alternate years, light and heavy crops of fruit. This naturally makes it impossible to maintain regularity of supply, which is most important in the case of an export product. Moreover, the fruit of a heavy crop is inclined to be undersized, and that of a light crop oversized and coarse. The physiological principles involved in this alternate cropping habit have been studied and methods to control it have been discovered.

Murrumbidgee Irrigation Area. After a prolonged drought in the Murrumbidgee Irrigation Area, very heavy rain fell in 1939, and floods were caused at a time when the ricefields were draining and the drains were full. The result of the waterlogging and floods was widespread damage to fruit trees. It was decided to conduct a thorough survey in order to obtain definite information regarding the number of thrifty and unthrifty trees, and the number killed by the floods.

This information was necessary in order to forecast future production, and was required by canneries, packing houses, and financial institutions. The survey was also designed to secure data regarding the effects on the health, yield and size of trees and vines, of the different cultural practices, &c.; in other words, the object was to find out as much as possible from past experience. A statistical analysis of the results has been made and will be of the greatest value to the whole area.

Frost Damage. Parts of the Murrumbidgee Irrigation Area, in common with other horticultural districts in Australia, are menaced by frosts. This problem was taken up by the Station, and it was found that dense belts of timber, such as mallee scrub, appreciably increased the incidence of frost in the locality. By clearing the mallee in certain districts the frost menace was removed. Effective methods have also been evolved for the protection of young citrus trees from frost during the period of their establishment, when they are particularly susceptible to frost damage.

Vegetables. Owing to the importance of increasing vegetable production during war time, and to the fact that the Murrumbidgee Irrigation Area has become one of the most important vegetable production centres and one of the most reliable districts in Australia, the Station is engaged in a comprehensive programme of research into production methods. Without going into details, it may be explained that as the industry is comparatively new in the district, there is naturally much to be learned. This is particularly so because the growing of vegetables on an extensive irrigation scale is new to Australia. The investigations include irrigation technique, fertilizer requirements, problems of seeding and germination, tillage and cultural problems, and weed control.

Post-war Developments. Though much has been accomplished as a result of the work at the Merbein and Griffith Stations, a great deal yet remains to be done. No doubt post-war planning and development will be along lines of a well-balanced economy of primary and secondary industries. Although it is likely that there will be a great development in secondary industries, there is no doubt that for years after the war the production of food will have to be maintained at a high level. Not only will there be a great demand for export, but our people should have more and better food so that they may be able to maintain not only sufficient calories, but sufficient vitamins, minerals, &c. The requirement will be to produce this food more economically with less labour and material, and the irrigation areas will undoubtedly have to play a major role in this development.

Now that many orchards on certain of the irrigation areas are between 20 and 30 years old, a second stage in their development is being reached. The average life of orchards under existing conditions is about 20 years. The problem now presents itself as to what should be done with the rather large areas which have completed one cycle of orchard growth. Much of the soil has undergone a change for the worse. Investigations should be conducted in order to determine the best use to which these lands can be put in the future and to decide whether they should be replanted and, if so, with what varieties, or if they should receive some reconditioning treatment and, if so, what.

The war has proved that Australia's irrigation areas are capable of producing large quantities of foodstuffs of an extremely wide range, and that they are more reliable and more valuable as food-producing centres than other districts. It is generally agreed that the new food industries developed in some of our irrigation areas during the war, and the expansion of pre-war production, have come to stay. Whilst, therefore, the somewhat indiscriminate settling of men on irrigation areas which followed the last war is not, of course, to be desired, there is a wide body of opinion that expansion in the quantity and quality of produce must develop. Much research will have to be carried out in order to accomplish this. Though a great deal has been done for the irrigation areas adjacent to the two Stations, extension of similar work to other existing districts and to new districts will be necessary owing to differences in soils, the crops grown, and general environmental conditions.

VIII.—FOREST PRODUCTS.

Australia possesses a great variety of timbers, of which many are of considerable commercial value, whilst some are unexcelled in the special properties which make them suitable for specific uses. Nevertheless, in the past we have not utilized our timber wealth to anything like the best advantage. Potentially valuable woods have been destroyed wholesale because their properties were unrecognized. Other species have been neglected or used only for a few of the purposes for which they might be employed. The result has been that Australia has paid enormous sums for imported foreign timber. Moreover, until recent years common practice in the timber-using industries in such matters as seasoning, milling, preservation, gluing, &c., was definitely bad and lagged seriously behind that of other countries. This was due in part to ignorance of information and methods already in existence and in application elsewhere, and in part to a serious lack of fundamental data regarding the properties, potentialities and correct methods of treatment of Australian timbers. When C.S.I.R. entered the field of forest products research, practical recognition was thereby given to an acute and long-felt need. The object of the work of the Forest Products Division is to provide information which will lead to the full and proper exploitation of Australia's timber resources and to assist the timber-using industries to discover and develop the most efficient methods of treatment and manufacture.

Seasoning. When the Division was established in 1928, the seasoning of Australian timbers was so bad that it was difficult to get local people to use them. To-day, seasoning in Australia is of as high a standard as anywhere in the world. This is due to the work of the Division and has been brought about by investigation of the air and kiln seasoning properties of Australian timbers and by the development of high performance kilns suited to local conditions. This has not been the result of laboratory work alone, but of intensive efforts in educating the industry by correspondence courses, classes, trade-circulars and individual advice. Plans and specifications for kilns in great numbers have been supplied, faulty kilns have been checked and corrected, and kiln operators have been trained in modern methods.

As a result of the development of efficient seasoning practices, Australian timbers have secured the popularity they deserve and are highly prized for their excellent properties. Moreover, the background of kiln seasoning knowledge and the widespread installation of kilns have been of the utmost value during the war period in meeting the sudden demands for seasoned timber. It has thus been possible to supply enormous quantities of kiln and air dried timber for cases and so avoid the extensive wastage of contents attendant upon the use of green timber for for this purpose.

PLATE 7.

Use of a projection microscope in the examination of wood structure. Measurements of the size, distribution, and frequency of the microscopic wood elements are of value in the identification of timber samples and in the industrial utilization of Australian woods.

Paper. At one time, paper was made throughout the world from softwoods because of their long fibres. Australia, with its extensive areas of hardwood forest and its shortage of softwoods, did not look a fruitful field for the paper maker, but it was left to the Australian research worker to show that the important factor was not the length of the fibre, but the relationship of the fibre length to the fibre thickness. It was demonstrated that Eucalypt timbers could make satisfactory paper, and this has led directly to the establishment of three large pulp and paper mills costing several million pounds. These mills employ some thousands of people and the output is worth well over £1,000,000 per annum. They have supplied much needed cellulose pulp for explosives and have enabled Australia to meet its paper requirements during the war with a minimum of imports. The plants will be extended after the war and will play an even greater part in Australia's national economy.

Tannin Extracts. A study of the tannin content of Australian trees led directly to the establishment of large extract plants in Western Australia. These have supplied a considerable proportion of Australia's requirements and in normal times provided for the export of high grade extract to overseas markets.

Wood Preservation. Work on the preservation of posts, poles, sleepers, &c., carried out in co-operation with the Postmaster-General's Department, the Railways Departments, Electric Supply authorities and Harbour Trusts, has proved of immense value. In the case of electric supply and telephone poles alone, every year that can be added to the life of existing poles means a saving of over £500,000 in replacements. Many years of life have been so added.

War Problems. When defence requirements called for a tremendous development of large stores, hangars, &c., work done on the use of modern "connectors" proved the solution of the problem of quick erection and minimum consumption of timber. Complete instructions for designers were issued to Australian and American engineers and have proved of the greatest value. Moreover, as buildings were erected further and further north, the problems of protection against rot and termite attack became more and more serious. In the solution of such problems the Division's studies of timber-attacking fungi and insects and of preventive measures came into effective use. As the fighting moved into tropical areas the problems of proofing all classes of material against fungi of numerous types became serious and the Division's knowledge of preservative treatments has helped materially in solving this difficulty.

Armies use huge quantities of ammunition, ordnance, food, medical stores, clothing, &c. Much of this material has to be transported and stored in wooden boxes. The choice of suitable timbers and methods of construction became important, for the quantities of timber involved ran into hundreds of millions of feet. To help to meet this position a large number of these boxes were re-designed with consequent substantial savings in timber, manpower and money cost. Design and testing of new boxes were followed up by close technical supervision of the factory operations.

PLATE 8.

Shear strength is one of the most important properties of the stressed-skin plywood covering of wooden aircraft. The illustration shows a shear test on a 3/16-in. hoop-pine plywood panel.

Studies of the properties and uses of Australian timbers have played an important part in solving many other war-supply problems. Apart from the general substitution of local timbers in common use, there has been the problem of the cessation of supplies of speciality timbers. Timber plays an important part in almost every aspect of modern war, and it is difficult to imagine what might have happened if detailed knowledge of local timbers had not been built up in pre-war time. For example, in the case of rifle furniture, correct seasoning reduced rejections from 17 per cent. to less than 2 per cent. at a time when losses could ill be afforded. Manufacturing technique for battery separators was established and standardized so that Australian timbers could give effective service in this important essential use.

Improved Wood. The background of mechanical testing of timber before the war, assisted by greatly increased efforts during the war, has shown that Australian timbers can be used in aircraft. The problem of making improved (compressed—impregnated) wood from Australian timbers has been overcome and very high grade material has been produced. The Division has manufactured blanks from which have been turned variable density wooden airscrew blades which have stood up to test. The improved wood blade is lighter than the metal blade and has other advantages. Manufacturers have been helped in the problems associated with establishing plants for this product, and four manufacturers are now producing improved wood, which has many other essential uses.

Veneers and Glues. The Division has carried out extensive work on veneer and gluing. The standard of gluing of plywood has been raised and a process developed for preventing borer attack in certain veneers. Thus, veneer which was formerly burnt, has been converted at negligible cost into the raw material for the manufacture of high grade plywood, immune to borer attack. The demand for plywood for war purposes has been greater than ever and has brought in problems of manufacture, special glues, &c. Thus birch has been replaced by Australian timber for aircraft plywood, and folding boats, pontoons, barges, &c., have been produced from plywood in great numbers. Timbers thought to be useless for plywood have yielded to thorough investigations, and as a result, for example, the plywood industry has been established in Western Australia using karri as a raw material.

Gluing problems associated with the manufacture of aircraft and a wide range of other products, have been overcome. All types of glue are now successfully manufactured in Australia. A serious shortage of safety match splints was averted by experimental work leading to the successful use of mountain ash for this purpose.

In addition to the matters mentioned here, the Division has handled innumerable enquiries, and has investigated a host of problems both of a war-time and peace-time nature, dealing, for example, with rot, insect and fire-proofing of timber, identification of timber including the preparation of identification keys for Australian and New Guinea timbers, marine borers, aircraft timbers, laminated structures, gums and resins, wood wool and wood flour, cooperage, wood stave pipes and tanks, shipbuilding, and milling and grading, including the preparation of standard specifications.

Post-war Developments. Looking back over the years the results of the Division's work show that it has paid for itself many times in savings to the community. It is gratifying to know that the timber industry in all States turns to the Division for help and advice in its everyday problems and has shown its appreciation of the assistance given by numerous gifts towards apparatus and equipment needed by the Division.

There are two main lines for future work; firstly, the more effective utilization of the small percentage of timber finally passing into use; and secondly, the elimination of the 90 per cent. waste now occurring in the forest, sawmill, and manufacturing industries.

In the field of more effective utilization, much work has already been done towards reducing the sizes of timber necessary for various purposes and thus towards conserving available supplies, but further reduction in sizes must await more fundamental research, particularly the long term loading investigations now being commenced. Otherwise structures with members of reduced size, although apparently sound when built, may fail after a year or two in service.

Further preservation investigations are necessary so as to obtain the longest possible life in timber used under exposed conditions. Durable timbers are becoming increasingly scarce and less durable species must, therefore, be given preservative treatment to meet the demand for posts, poles, sleepers, &c., which must greatly increase in the post-war reconstruction era. New and improved methods of using timber involving the latest practices of impregnating timber with resins and other materials and new veneer and plywood techniques must be developed.

Present day methods of conversion and utilization of timber are very wasteful. Of the fallen tree, less than 20 per cent., on the average, is ultimately utilized in Australia. The balance is left behind as low grade logs, tops and branches in the forests, as sawdust and waste wood in the mill, and as sawdust, shavings, off-cuts and dockings in the case mill and furniture plant. Some of the waste is used for fuel, often very inefficiently; much has come to be regarded as an inevitable loss in timber conversion. Taking into account unsuitable trees and lower grade species left in the forest, not 10 per cent. of the timber grown is utilized.

In the elimination of waste, the first requirement is the investigation of Australian milling practice, which is in much the same position as seasoning was when the Division was formed. An initial survey, followed by an investigation of milling methods, development of the best types of equipment for various Australian conditions, and education of the millers in these methods are required. In other words, the Division must repeat, in the milling field, the work which, in the seasoning field, has raised Australian seasoning practice to such a high standard. Improved methods will bring lower costs and permit milling to extend to classes of logs not now within economic range.

Short logs, small logs and off-cuts can produce high grade material in small sizes and the utilization of these by laminating and other means can result in considerable increase in recovery from the forest. Work, in the past, has been confined largely to the principal species. Future research must be applied to secondary species which to-day are left in the forest.

At the present time, although sawdust represents one of the largest single forms of waste, its principal use is as fuel. In the past it has not been considered suitable for pulp manufacture but future investigations should aim at overcoming its disabilities in this respect. In conjunction with other forest wastes, it should be looked upon as the raw material for a wide range of useful products. There is also a very important field for investigation in the expansion of the manufacture of paper and other pulp products such as building boards. The latter will be required in almost unlimited quantities, and can contribute more than any other single material towards the improvement of Australian housing conditions.

The use of plywood and veneer is an effective means of reducing waste, but the present commercial plywood species in Australia are becoming scarce. A change-over to other species is inevitable if the industry is to continue on its present basis. This brings in a wide range of problems on the peeling, drying and gluing of new species.

It is becoming increasingly evident that if advantage is to be taken of the latest technological developments, planning of the Australian timber industries will be necessary. The integration of industries, whereby the waste of one becomes the raw material of another, whereby services in common such as power and steam are provided from central plants, and whereby timber workers are housed in small townships with amenities, must replace the existing order of large numbers of small mills scattered more or less indiscriminately with all the attendant disadvantages. The basis of such integration of industry with its improved utilization, lower costs and better working conditions is a thorough knowledge of all the raw materials and processes involved.

IX.—FOOD PRESERVATION.

Owing to the facts that Australia lies inconveniently far away from the main food importing countries of the world and that it is itself a land of long distances, the preservation and transport of perishable products involve problems of great importance. In order adequately to investigate these problems C.S.I.R. established a Division of Food Preservation and Transport at Homebush, New South Wales, through the courtesy of the Metropolitan Meat Industry Commissioner in that State ; the Division maintains a subsidiary laboratory at Brisbane as a result of facilities accorded by the Queensland Meat Industry Board. In this field, C.S.I.R. can claim to have rendered most valuable service ; for its work on food preservation and transport has made possible the export of products which previously could not be sent overseas and has very greatly increased the efficiency of storage practices, which through lack of adequate knowledge had resulted in the past in heavy losses.

The most suitable conditions for storage vary for different products, sometimes widely, occasionally only slightly. Beef must be handled differently from mutton ; and fruits all have their own idiosyncrasies which may differ in different varieties of the same fruit. Further, it is not only the conditions during storage and transport that are important ; the previous history and treatment of a product affect its storage life and are often the main factors determining its suitability for export. It is clear, therefore, that if Australia is to overcome the handicap of her geographical position accurate information regarding each exportable product must be available. The accumulation of these essential data, involving painstaking research and carefully controlled experiments, is the function of the Council's Division of Food Preservation and Transport.

Chilled Beef. The years 1920–34 were marked by increasing difficulty in overseas marketing of Australian frozen beef in competition with South American chilled beef. Owing to the period of the voyage from Australia to England being more than double that from South America, Australian beef could not be exported in a chilled condition without very serious losses. A thorough scientific study of the processes of slaughtering, cooling, and storage of chilled beef enabled methods to be devised for its safe export, despite voyage periods of up to 60 days in duration. Successful experimental shipments in 1934 soon led to the establishment of an important trade with negligible losses. By 1939 the export of chilled beef had risen to 29,000 tons per annum, valued at £1,000,000. Actually this work necessitated a number of complex investigations into the seasonal and geographical variations of the micro-organisms responsible for spoilage and their rates of growth under different climatic and other conditions, into the most suitable rates of cooling the sides of beef, and the control of chilling room and storage atmospheres. It also involved a great deal of work in the detailed study of both experimental and commercial shipments of chilled beef to England.

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Fruit. The main object of the fruit investigations conducted by the Division has been to determine the best conditions for the storage and transport of Australian-grown fruits. New methods of controlling wastage in plums shipped to England were discovered. Marked improvements in the handling and cold storage within Australia of apples, pears and oranges have also resulted from the work of the Division. The proper conditions for ripening bananas have been defined and the results have been adopted widely. The improvements were greatest in the warmer parts of Australia and a considerable increase in the sale of bananas occurred in Brisbane as a result of improved ripening. This work has also assisted materially in the development of a local banana industry in Western Australia.

Eggs. Serious losses occurring in Australian eggs exported to England or stored locally have often threatened the stability of a trade which, in exports alone, was valued at more than £600,000 per annum in the pre-war years. In an intensive five-year programme of investigations starting in 1937 the main causes of loss were found to reside in the methods of handling and treating the eggs on the farms. As a result of the Division's investigations remedial measures have been devised for application in the post-war years.

Fish. The safe frozen storage life of a number of species of Australian fish and the conditions necessary to ensure a maximum period of holding in the frozen condition have been determined. The quality of some species of Australian smoked fish has been greatly improved by the development of methods for the control of conditions during smoking.

War Problems. Following the outbreak of war, the work of the Division was reorganized and problems not directly concerned with the war were abandoned. A great deal of attention has since been given to problems associated with the dehydration and canning of foodstuffs aimed at improving quality and retaining maximum nutritive value. Surveys of food processing plants have been made, the standards of quality improved, and production largely expanded. The Division has, in fact, played a most important part in assisting the enormous extension of the canning industry during the war, particularly in vegetable and fruit juice canning. The main objects have been to ensure that the products are safe bacteriologically and are of high quality. Work on the efficiency of can-making and closing and on the lacquering of cans has been particularly important. The Division has been able to give valuable technical assistance and advice in connection with the formulation of many specifications for processed foods and has given courses of instruction in fundamental and practical aspects of the canning and drying of foodstuffs. It has played an important part in the development of vegetable, meat and egg dehydration, which are new war-time industries. Processing procedures have been developed for the preparation of canned and bottled fruit juices and a production programme to meet the requirements of the fighting Services has been organized. Tests of a wide range of internal coatings for cans have been made and recommendations given for types suitable for withstanding the corrosive action of fruit juices and the sulphide staining of meat packs. The causes of numerous cases of spoilage in canned foods have been determined and appropriate corrective measures furnished. The keeping quality of dried apples has been greatly improved by

methods of sulphuring developed in conjunction with other Australian laboratories. Valuable knowledge has been acquired on the properties and limitations of packaging materials for use in place of tinplate. Methods of preparing pectin from apple and citrus residues have been developed, as also have methods for increasing the storage life of apples by placing a film of oil or wax on the skin so that the fruit can be stored in places where refrigerated space is not available.

Post-war Developments. The general objects of the Division's work will be unchanged in the post-war years. Most of the work now in progress or temporarily abandoned following the outbreak of war will have to be continued and extended after the war. The exact programme of work will depend on developments in the food industries in Australia, and particularly on the trends in food exports. If, as seems likely, there is increased overseas trade in processed foods, it will be essential to increase efficiency in the processing industries, and to maintain the highest possible quality standards in order to ensure successful competition with exporters from other countries.

Work on food processing for the Australian market, with particular emphasis on improvements in quality and nutritive value, must be developed. Among the more important lines of work in this connection, the following may be mentioned—(*a*) the storage and handling of fruit, (*b*) the preparation and storage of fruit juices, (*c*) the canning of vegetables, fruits, meat, and fish, (*d*) the preparation and storage of certain dehydrated foods, and (*e*) the freezing and curing of fish. The export of chilled beef to England should be resumed after the war, and intensive work on improvements in the quality of the beef on arrival, particularly the "bloom", will have to be resumed. Developments in other countries indicate that a trade in frozen fruits and vegetables is likely to develop in Australia in the near future. To assist this, much work is needed to determine the most suitable Australian-grown varieties and the best processing methods. Plans to begin such studies in co-operation with the New South Wales Department of Agriculture are being prepared. Basic information is required with respect to problems concerned with the handling and transport of meat in Australia, with particular emphasis on the supply of Queensland beef to the southern States, and on the handling and storage of fresh vegetables, with particular emphasis on vitamin retention and reduction of waste. The importance of nutritional problems is now widely recognized, and there is a large field of work awaiting attention in connection with the determination of quality standards for various foodstuffs.

It is evident that the Division can do, and has already done, a very great deal not only to assist the development of an export trade in perishable foodstuffs, but also to increase efficiency in the food processing industries and maintain the highest possible quality standards for consumption in Australia.

X.—FISHERIES.

The exploitation of Australia's marine resources has proceeded slowly, one of the main reasons being the absence of knowledge regarding the location of fishing grounds, the migrations and other habits of fish, and suitable methods of catching different varieties under the conditions which prevail in Australian waters. Broadly, there are two main types of edible fish, viz., demersal or bottom-dwelling fish caught by trawling, and pelagic or surface-swimming fish caught by nets or lines of different sorts. In 1909 the Commonwealth Government initiated investigations into the occurrence of demersal fish by the steam trawler F.I.S. *Endeavour*, but these efforts ended tragically with the loss of the vessel and all hands in 1914. For some years following the war of 1914–18 interest in the development of fisheries flagged and it was not until 1933 that the Commonwealth Government, as a result of recommendations made jointly by C.S.I.R. and the Development Branch of the Prime Minister's Department, decided to engage in a programme of fishery investigation under the following main heads :—

(1) to procure a vessel specially designed for exploration for pelagic fish, but which could also carry out certain investigations on demersal species ;
(2) to undertake experiments on the canning of fish and the manufacture of fish by-products ;
(3) to undertake tests to determine the best methods of curing and preserving fish ;
(4) to undertake, in co-operation with State authorities, a study of the systems of distribution of fish in each State.

In 1935 the responsibility for fisheries investigation was placed directly on C.S.I.R. As marine biological investigations, except perhaps of a somewhat isolated nature, marked a departure in scientific work in Australia, and as they could be prosecuted effectively only if properly trained men were available, active research on the lines proposed necessarily developed slowly. However, plans were immediately put in hand for the erection of a marine biological laboratory and the construction of a fisheries investigation vessel, for the appointment of scientific staff, and for certain minor investigations to be initiated. Arrangements were also made for test flights designed to observe from the air the occurrences and movements of pelagic fish. In 1938 delivery was taken of the fisheries investigation vessel *Warreen* and active work at sea was commenced. In the following year the Council's marine biological laboratory at Cronulla (N.S.W.) was completed.

War Organization of Fisheries.

Though it was not until shortly before the outbreak of war that the Fisheries Division was equipped actively to pursue its work, it already has a substantial record of achievement to its credit. Since the war commenced, basic and long-term investigations have been reduced to a mere maintenance level and the Division has concentrated its activities on problems directly related to the war effort. In 1943 certain senior

PLATE 9.
Research vessel *Warreen*, overall length 82 feet.

WARREEN

members of the staff and the facilities of the Division generally, were made available, at the request of the Department of War Organization of Industry to establish a co-ordinating authority so as to secure during the war period maximum fish and marine production with the minimum of manpower and equipment. In that work the knowledge and information accumulated by the Division have been invaluable. The fisheries investigation vessel was transferred to the Department of the Navy for war purposes in 1942.

Pelagic Fisheries. As regards pelagic fisheries, with Australia's immensely long coastline, and with only one vessel available for exploratory work, investigations had to be limited mainly to the south coast of New South Wales and the north-east of Tasmania. This was particularly necessary since observations must be repeated on the occurrence of fish in any particular area over a series of years before definite and final conclusions can be drawn. The data collected up to the time when the vessel was transferred to the Department of the Navy have already made it possible to form an estimate of the seasonal and annual variations in the occurrence of pelagic fish and of the fishing results likely to be achieved in the areas explored. Though it appears that pelagic fisheries in these areas are not likely to yield results comparable with those in certain well-known fishing grounds in other parts of the world, there is a good prospect of substantial development. The results are now being followed up actively by the Tasmanian Government and private enterprise and are being applied on a commercial scale. A profitable seine-trawling ground has been shown to exist off the east coast of Tasmania and it is anticipated that a successful industry will develop. The exploratory work has recently been extended to Western Australia, where aerial reconnaissance and other observations have disclosed the occurrence of considerable shoals of fish.

Aerial Surveys. The area over which observations regarding the occurrence of fish can be made by a research vessel or by fishing boats is obviously very limited and observation from the air from 'planes made available by the Department of the Air has greatly extended the range over which exploratory work can be conducted. Information of very great value has been obtained in this way. In Australian waters, where there are so few fishing craft, failure to observe the occurrence of fish within a limited range, over areas sometimes covering tens of thousands of square miles, is likely to be interpreted as evidence of the non-existence of fish stocks or of a great fluctuation in their seasonal abundance. The aerial reconnaissance work carried out by the Division has attracted wide attention in other countries, particularly in the United States of America, where Navy blimps are now helping in the war food programme. Aerial scouting has been demonstrated as a practical means of increasing the effectiveness of fishing fleets and this is a line of work which should be followed up actively after the war. It appears not unlikely that Australia may have to develop special techniques, utilising aircraft working in conjunction with fishing vessels, for catching the large shoals of fish which occur in parts of our extensive coastal waters.

PLATE 10.

Air photo taken near Flinders Island, Bass Strait, of shoal of Australian salmon (*Arripis trutta*) with a large shark in its midst. White lace-like objects are surf. Dark objects on top and bottom are marine growth. The shark is a very big one and the shoal is over 100 yards long.

Conservation Measures. In addition to the above exploratory work, investigations have been conducted on growth rates of important species of fish, age at maturity, and many other biological factors determining replacement rates, with a view to control so as to prevent depletion of sources of supply. Based on the knowledge thus obtained, conservation measures have been devised which, while protecting the stocks, permit of the taking of maximum quantities. Methods of predicting each year the probable nature and extent of runs of important pelagic fish species are being devised.

Agar. Before the war, Japan supplied practically the whole of the world's requirements of agar, which is used mainly for meat canning, but is also essential for bacteriological purposes. Investigations were conducted by the Division to ascertain if certain species of Australian seaweeds could be used for the production of agar. Satisfactory methods of processing have been evolved, production on a commercial scale has been undertaken by interested firms, and a new industry has thus been established.

Vitamins. Before the war about 85,000 gallons of cod-liver oil were imported into Australia annually. The cessation of these imports resulted in a very serious deficiency of vitamin A. Investigations conducted by the Division showed that the livers of certain species of shark were very rich in vitamin A content, and suitable processes for treatment and extraction of the oil were devised. There is now in Australia a considerable and important industry in the production of shark oil and of vitamin A concentrates of high quality.

Among other results of the Division's investigations, and of evidence and advice furnished by it, the following may be mentioned, viz., (*a*) the erection of a plant for the conversion of fish offal into fertilizer and oil, and (*b*) marked improvements in methods of processing fish by smoking and canning. Plans have been prepared for the establishment of a coastal whaling industry to supply oil urgently required by Australia and the Allied nations and it is anticipated that effect will be given to them before long.

Post-war Development. Whilst results of very great value have already followed the work of the Division, and whilst a considerable mass of basic information has been obtained, there remains a large volume of work to be done; in fact, one may say with respect to the scientific investigation of Australia's marine resources that the fringe only has so far been touched. Investigations should be pursued to establish the commercial value of trawling grounds, e.g., off the eastern coast of Tasmania, in the Great Australian Bight, and off the New South Wales coast. There are indications that the better known waters from which sharks are caught are being depleted; work should be conducted to find new grounds. Investigations are necessary for the development of the whaling industry, which would be of great value to the Commonwealth. The factors, economic and biological, affecting the industry should be studied. Methods of securing maximum yields and use of products such as oil, meal, and glandular extracts should be investigated, and aerial observations of the occurrences and migrations of whales should be conducted. In connection also with the occurrence of pelagic fish, aerial reconnaissance work should be greatly developed.

There is an important field of work requiring investigation in connection with the development of the oyster industry ; there is every reason to believe that considerably increased production would follow as a result of research on more intensive methods of cultivation and on a number of problems affecting the growth of oysters, about which little is at present known. The crayfish, crab, and scallop industries are capable of substantial development if the necessary exploratory and biological work were undertaken. The search for suitable seaweeds for the production of agar, Irish moss and other products should be intensified, processes for treatment should be investigated, and the physical and chemical properties of the resulting products studied. The reclamation of fish by-products, and the use of inedible species of fish for the production of fish-meal for stock feed, and oil for industrial use, are important industries in other countries. There is no reason why similar industries should not be developed in Australia, provided that the necessary information is available. A considerable amount of work is necessary to devise methods for improved fish canning and smoking processes. As already indicated, the Division has made extensive surveys of the seasonal and geographical distribution of pelagic fish, chiefly tuna, pilchards, mackerel, anchovy, and sprat. The result is that there is now a large body of information available awaiting the all-important but difficult final fishing tests, which will have to be conducted under the supervision of experienced pelagic fishermen, since the technique of capture is far from simple and long experience in the methods employed is necessary. A great deal of further work will have to be done on conservation methods if our existing fisheries are not to be still further seriously depleted.

In most other countries sea food forms an important and relatively inexpensive part of the national dietary. In Australia fish was scarce and expensive even under pre-war conditions. Whilst this was no doubt due partly to causes other than the absence of knowledge regarding the occurrences and habits of Australian species of fish, sufficient has been said to show not only that scientific investigation can play a most important part in developing the exploitation of our marine resources, but also that there is a vast field of problems awaiting investigation.

XI.—NATIONAL STANDARDS.

Some time before the war, following the decision of the Commonwealth Government to extend the activities of C.S.I.R., steps were taken for the establishment of a National Standards Laboratory which was to be in some measure the Australian counterpart of national institutions in other countries, such as the National Physical Laboratory in England and the Bureau of Standards in the United States of America.

Accurate measurements are essential for efficient and economic methods of production in most industries. By the careful control, i.e., by measurements of one kind or another, of all the processes of manufacture, not only is the cost per unit decreased, but the quality of the product is improved. This may be control of length, mass, volume, temperature, humidity, density, pressure, and so on, and such control can be obtained only by the use of measuring instruments. In order that the measurements may be accurate, obviously the instruments themselves must be accurate, and this cannot be ensured unless provision is made for checking or calibrating them periodically, i.e., comparing them with instruments of a known higher degree of accuracy.

One lesson we have learnt from the war is that interchangeability and mass production are wholly dependent on a sound system of gauges and on the use of precision measuring equipment. In mass production individual fitting is a thing of the past. Any one of thousands of components of one kind must be a true and satisfactory working fit with any one of a similar number of other components. This is possible only if manufacture is controlled within very fine limits of accuracy, and this can be achieved only by the use of carefully designed and accurately made gauges.

Gauges and other measuring devices are, of course, subject to changes with time and use and must, therefore, be calibrated periodically. For such purposes a factory requires to have master gauges with which the working gauges used in the shops can be checked. These master gauges must, however, in turn be periodically calibrated against gauges and instruments of a still higher degree of accuracy. These are called sub-standards, and the accuracy of these must again from time to time be checked with the national primary reference standards. It is the function of a National Standards Laboratory to maintain these standards and to provide facilities for comparing sub-standards with them.

There are three Divisions of the Laboratory, viz., (1) Metrology, (2) Physics, and (3) Electrotechnology. When war was declared in 1939 steps had already been taken for providing a building and the necessary equipment for the Laboratory and for training the key personnel. During the past four years the work of the Laboratory has been devoted to war-time problems, and it will be apparent from the information given in the following paragraphs that the work it has carried out has been of the utmost importance to the prosecution of the war and that it was indeed fortunate for Australia that the necessary preliminary steps for establishing the Laboratory had been taken prior to the outbreak of war.

Metrology Division. The Metrology Division of the Laboratory is concerned mainly with the production and calibration of gauges and other measuring instruments required for the manufacture of precision machinery and munitions. It has acted as the control centre in New South Wales for the wide network of Directorates and Inspection Departments responsible for the acceptance of equipment manufactured for the Services. It has acted on behalf of the Directorate of Machine Tools and Gauges in sponsoring the manufacture of precision instruments such as slip gauges, pitch measuring machines, micrometers, and workshop projectors. Special measuring equipment not available from abroad has been designed and manufactured by the Division.

Slip Gauges. The production of slip gauges affords a striking example of the valuable work carried out by the Division. These gauges are pieces of metal whose surfaces are flat and parallel to 5 or 10 millionths of an inch and whose dimensions between these parallel faces are known to some 10 or 20 millionths of an inch. The extreme accuracy of these surfaces is such that when one slip gauge is made to slide over another the gauges adhere without any other agency. By selecting appropriate gauges, a desired dimension can be obtained by combining the gauges by the property of adhesion or " wringing ", as it is termed. In 1939 production facilities for slip gauges in England and the United States of America were hopelessly inadequate to meet war needs and the supplies available to Australia were negligible. The Directorate of Machine Tools and Gauges allocated to the National Standards Laboratory the problem of investigating methods of production. As may well be understood, this problem involved an immense amount of work of the highest degree of accuracy. It was solved with great success and the urgent demands necessary for the production of munitions in Australia were thus met.

Inspection Services. On behalf of Inspection Services, periodical visits have been made to all industrial establishments having mechanical testing machines. These machines have been tested, personnel and methods examined, and recommendations made to the Inspection Services concerning the acceptance of results of tests from such Test Houses.

The staff has represented the Laboratory on various Committees of the Standards Association of Australia, the Optical Munitions Panel, and the Panel Advisory to the Secondary Industries Commission of the Ministry of Post-War Reconstruction. Educational lectures have been given at Sydney University, at Sydney Technical College and to engineering institutions. Staff have been trained for industrial establishments, and methods of measurement and production have been displayed at the Laboratory to tool-room staff of manufacturers.

Physics Division. The need for expanding industry and the requirements of the Services during the war necessitated a rapid development of the work of the Physics Division. Since it was established early in 1941 the Division has undertaken the testing and calibration of all temperature-measuring equipment in munitions manufacturing establishments in New South Wales. It has rendered marked assistance in the manufacture and testing of pyrometric equipment used in munitions manufacture. This has resulted in the maintenance of accurate temperature control in furnace equipment and the reduction of spoilage in the

heat treatment of steels and alloys. In the field of low temperature work several problems in the desiccation of blood serum for the Red Cross Society have been solved. An instrument for the rapid measurement of the humidity of the atmosphere from an aeroplane has been successfully developed for the R.A.A.F. The Division has advised on a wide range of other heat problems, the total effect of these activities being of considerable economic importance and contributing materially to the war effort.

Optics. In optics the Division has also investigated a wide range of problems too numerous to be referred to here in any detail. They include the supervision of the properties of all optical glass manufactured in Australia, the methods of manufacture of searchlight and heliograph mirrors, tests of black-out materials, examination of numerous prototype optical munitions instruments, and the supervision of the optical properties of naval gun-sight telescopes. One investigation alone resulted in a saving in cost of manpower to the value of about £20,000.

Photometry. In photometry, investigations have been conducted successfully for the Departments of the Navy and Labour and National Service on the measurement of sky glow at night in black-outs. A telephotometer has been designed and constructed ; this is an instrument important in camouflage work for measuring from a distance, e.g., from an aeroplane, the brightness of camouflaged objects.

The Physics Division has been the centre of research and development in Australia for aids to night vision for the three Services. One of the main problems was to provide pilots, navigators, and observers in aircraft with conditions such that they could work with their maps and instruments in comfort, and yet when the line of vision was directed from their work to objects outside the aircraft, landmarks, enemy aircraft and other targets would be readily visible. Pre-war types of aircraft lighting were entirely unsatisfactory in this respect. Night vision was seriously impaired and visual fatigue common. By applying the results of research into the physical aspects of vision, methods have been devised which ensure excellent night vision to pilots and crew and which also greatly reduce visual fatigue. The method recommended for this purpose by the Laboratory has been adopted by the Department of Air in the construction of Australian aircraft.

Colorimetry. A very wide range of colorimetric problems has been solved for the Services in connection with welders' goggles, tracer bullet goggles, food preservation, &c. Anti-aircraft spotters searching for aircraft run the risk of permanent damage to the retina of the eye, known as eclipse blindness, through the concentration of the sun's radiation. A form of goggle has been developed and patented by the Section which eliminates this danger and at the same time makes possible the search for aircraft very close to or even in direct line with the sun. These goggles are being manufactured in large numbers for the Departments of the Navy and Army.

PLATE 11.
The National Standards Laboratory, Sydney.

Electro-technology Division. Although the primary electrical standards—the ampere, the volt and the ohm—will be maintained by the Physics Division, it will be the responsibility of the Electrotechnology Division to provide for the maintenance of multiples and sub-multiples of the primary units and for the calibration of derived electrical standards required by industry. While some electrical standards work has been called for during the war, the major activity of the Section for the last four years has been associated with the development for manufacture in Australia of instruments required by the Department of the Army for the control of gunfire. The purpose of these instruments is to enable artillery to benefit from the use of radar. Since all previous fire-control instruments were based on visual observation of targets, they were not readily applicable to radar observation. One of the coastal artillery instruments developed by the Laboratory is reported to be more comprehensive in its scope than any other plotting instrument in the British Empire or the United States. The work of the Division involved, therefore, the original design of new types of equipment of this sort, and in all, seven different kinds of this type of equipment have been designed and put into use by the Department of the Army.

Degaussing. The Division has also given essential assistance to the Department of the Navy by doing the fundamental examinations required for degaussing ships as a protection against magnetic mines, and has sent the Department of the Navy over two thousand recommendations for the magnetic treatment of ships.

Tropical Requirements. More recently, with the realization on the part of the Services that special attention had to be given to the quality and type of materials incorporated in Service equipments if they were to withstand the rigours of the tropical climate, the Division has undertaken the investigation of defects of design and materials used in all electrical equipment. Through the researches already carried out, the Section has been instrumental in advising the Services as to the way in which electrical equipment must be made for use in tropical climates.

Post-war Developments. The post-war activities of the National Standards Laboratory are dealt with in the following pages in conjunction with those of the Council's Radiophysics Laboratory.

PLATE 12.

A worker in the National Standards Laboratory is shown measuring, by means of a floating micrometer, the dimensions of a screw gauge, used for checking the accuracy of screw threads. Such gauges play an important part in munitions production by ensuring that parts made in separate factories are interchangeable.

XII.—RADIOPHYSICS.

The Radiophysics Laboratory was established at the beginning of the war to provide the research facilities which were required by the fighting Services for the development of radar equipment. The necessity for such a Laboratory was not only felt by the Australian authorities, but was specially recommended by the British authorities because of the extreme difficulty—due to the great distance of British establishments from the scene of operation—of providing equipment of the right sort for the conditions of warfare in the south-west Pacific area. The specific task of the Laboratory was, therefore, to investigate the conditions of the Pacific war and the requirements of the Services, and as a result, to design equipment specially suited for this theatre.

Since 1939 the Laboratory has been instrumental in introducing into Australia new methods for generating and detecting radio waves. Through its activities this knowledge has been made available to the Services very much earlier than would have been possible if they had had to rely on information from overseas. The Laboratory has, since 1939, designed some fifteen different varieties of radar equipment for the three Australian Services, each of these projects requiring specialized attention to the particular operational needs of the Services. Most of the work of the Laboratory is secret and cannot be disclosed. When the full story of radar developments can be told it will reveal remarkable progress in research and will be of much public interest. Two examples may be given as illustrative of the activities of the Laboratory.

Radio-location. In offensive warfare in which a combined assault is made at a point on the shore-line of enemy-occupied territory, provision must be made for warning against attack by enemy aircraft. This warning provides an opportunity for active steps to be taken to combat such an attack by anti-aircraft fire or by the use of fighter aircraft. In the offensive operations in New Guinea and New Britain, the objective has usually been to capture an airfield or strip as soon as possible after the landing is made on the coast, so that aircraft may be flown against the enemy. In this war the only satisfactory method for obtaining early warning of the approach of enemy aircraft is that provided by radar equipment. The terrain in which such operations take place in the Pacific is often completely devoid of roads and other amenities of civilization: it is commonly covered by jungle growth and experiences the most severe conditions of a tropical climate.

Radar equipment for early warning purposes must be capable of transportation to the beach-head by landing craft from a point sufficiently near, to which the equipment has already been transported by aircraft. Air transportation is essential if the equipment is to be moved with sufficient rapidity over the very large distances from a base to the scene of operations. These conditions differ completely from those found in the European theatre of war.

Air Warning. In the United States and England, the research establishments formerly had no direct contact with the Pacific war, and consequently there was no realization of the special requirements. They were, however, fully understood by the Radiophysics Laboratory before the Japanese entered the war. As a result, it was possible very soon after the Japanese began their offensive, for the Laboratory to supply sets of air-warning equipment to the R.A.A.F. These sets provided air-warning facilities in north Australia and Papua of a decisive character in the early stages of the Japanese attacks. The equipments were readily transportable by air and as a result were installed very soon after the beginning of the war with Japan.

Before they were installed fighter aircraft were incapable of meeting the Japanese attacks, but this situation completely changed with the provision of early warning, which enabled fighters to be got into the air and to be directed from the ground.

Since that time the development of this type of equipment has been continuously followed by the Laboratory, and there have now been produced in Australia relatively large numbers of suitable equipment. The Australian source of supply is the only source at present available, and these equipments are being sent, therefore, not only to the Australian Services but also to the American forces in the Pacific theatre.

The operation of reconnaissance and attack aircraft against enemy shipping is vitally affected by adverse weather conditions and by the impossibility of undertaking night operations without some aid. These defects can be removed by equipping the operational aircraft with radar equipment, which permits it to observe ships in any conditions of weather, or at night, and to launch offensive strikes in these conditions. The same equipment provides exceptionally good navigational aid to the aircraft, since the coast-lines within range can be observed, and with the assistance of radio beacons at selected points on shore the exact position of the aircraft can be determined by its navigator. Such equipments have been designed and are at present widely used by the R.A.A.F. as a result of production in Australia.

In addition to providing the research facilities resulting in the production of such equipments, the Laboratory has given extensive assistance to the Services in the form of information on new methods for the use of radio equipment and in the instruction of Service personnel.

Radio Propagation. In addition to its work in the Radiophysics Laboratory, the Council has carried out radio research in co-operation with the Postmaster-General's Department and the Universities of Sydney, Melbourne, and Queensland, under the direction of a Radio Research Board. Earlier investigations dealt particularly with the problems concerning atmospherics and fading, and a very comprehensive survey has been made of these problems in so far as they affect the transmission and reception of wireless waves in Australia. Work on this subject is still in progress, as the range of wave lengths used in radio communication has extended rapidly in recent years.

The work on fading and other transmission problems resolves itself very largely into an investigation of the nature of the ionosphere. To appreciate the importance of the ionosphere, it is necessary to understand something of the transmission of wireless waves. These, though they do not travel in straight lines as do light waves, are capable of only a limited amount of refraction or bending, and thus (remembering that the earth is a globe) it should only be possible to pick them up within 100 miles or so of the point of their origin. Actually, as everyone knows, wireless communication can take place over several thousands of miles. Long-distance transmission is accomplished by means of what are known as "sky waves". These sky waves (as compared with "ground waves," which are those waves whose path "hugs" the surface of the earth, and which die out within about 100 miles of the transmitter) follow a path which leads upwards and away from the earth's surface, and then, striking the ionospheric layers, are reflected back towards the earth, where they can be picked up by wireless receivers. Fading occurs at points where both the ground and the sky waves from a station are being received simultaneously. These two waves interfere with each other, sometimes pulling together, when the volume of sound from the receiving set will increase, and sometimes cancelling out, when fading results. Fading only occurs after dark, for during the day the intense power of the sun saps practically all the energy from the sky wave, which, therefore, does not enter the picture, reception depending on the ground wave alone.

In long distance communication, when only sky waves are used, fading also occurs, because the sky wave is a variable thing and, moreover, more than one may reach the receiving station, having followed different paths; and these waves will interfere with one another.

It is clear, therefore, that knowledge of the nature of the ionosphere and of the waves that are reflected downward from it may be very valuable in helping to improve the technique of long-distance transmission and reception. Already the Council's investigations have added greatly to our knowledge of the gases in the region between 30 and 150 miles above the earth, knowledge which is of importance to meteorology as well as to radio science.

During the period of war the activities of the Radio Research Board have been greatly extended. The three Services—Navy, Army, and Air—are now represented on the Board, and a special committee of the Board (namely, the Radio Propagation Committee) has been formed to deal with problems which particularly affect the Services concerned. Co-ordination has been established between this committee and similar committees in Great Britain and America. Ample opportunity has been found for the application of results of fundamental research in which the staff of the Board had been previously engaged, and it has become necessary to resume this type of research to supply information which is urgently required in improving the reliability of radio communication.

Apart from the immediate results which are being obtained a very valuable record is being accumulated of field observations which have been made necessary and possible by the war, and the careful examination of such records will in turn undoubtedly suggest new lines of investigation which can be undertaken with advantage.

Post-war Developments. Coming now to the post-war activities of the National Standards and Radiophysics Laboratories, there are two main conditions which must be fulfilled if the phenomenal industrial development of the Commonwealth during the war is to be maintained. The first is that there must be adequate facilities within Australia for the maintenance of accurate measurements in engineering and physics. This need has been widely felt during the war and facilities have been provided for the purpose. These facilities must be maintained and adapted to peace-time needs. The second condition is that Australia cannot, if our industries are to be developed effectively, afford to revert to the pre-war conditions under which we relied so largely on scientific information from overseas. Adequate research facilities, accompanied by close liaison with industry, must be provided in Australia.

Many technical developments which have occurred during the war must have far reaching effects on peace-time industrial development. Typical of these are the advances in radio technique, which would place Australia in the forefront of technical development of radio aids to navigation of civil airlines. Such unique advances represent great potential for industrial expansion and for providing employment for our technicians and scientists ; they would lead to the establishment of self-contained industries within the Commonwealth.

The National Standards and Radiophysics Laboratories would form one of the chief organizations which could contribute to the fulfilment of the conditions referred to above. In order to give a clear idea of the wide range of post-war activities of these Laboratories it would be necessary to enter into technical details, which cannot be dealt with here. Broadly, the main functions of these Laboratories would be as follows :—

(*a*) To maintain Commonwealth standards of measurement and to certify scientific and industrial instruments and materials.

(*b*) To carry out scientific investigations in physics necessary for the development of secondary industries.

(*c*) To undertake fundamental research in physics and engineering for the advancement of technology in Australia, and

(*d*) To furnish the fighting Services with such scientific advice and guidance as they may require.

Weights and Measures. Under the Constitution Act the Commonwealth has power to legislate with respect to weights and measures, but it has not yet exercised that power. Attention has already been directed to the need for providing and maintaining national reference standards in Australia, and it was mainly for that purpose and for the purpose of affording facilities for the calibration of sub-standards that steps were taken before the war for establishing a National Standards Laboratory. Having regard to the importance of post-war reconstruction and the plans which are being prepared for the development of secondary industries, the passing of the necessary legislation should not be long delayed. The National Standards Laboratory would be the custodian of our national standards of measurement which, as the war has proved, are essential to efficient industrial development. It would be responsible for the calibration of yard and metre scales, weights and balances, surveying tapes,

precision gauges of all sorts, screws, micrometers, surface plates, straight edges, &c.; in short, of any apparatus for the measurement not only of length, but also of area and volume. It would have charge of the Australian legal electrical standards—the ampere, the unit of intensity of electric current; the volt, the unit of electro-motive force; and the ohm, the unit of resistance. It would be responsible for the calibration of electrical measuring sub-standards of all kinds. It would deal with standards of heat, light and sound. It would carry out tests of all classes of instruments for measuring and recording temperature, e.g., clinical thermometers, electrical resistance thermometers, thermocouples, and optical and total radiation pyrometers. It would be responsible for maintaining the standards of illumination for Australia, and for determining the acoustical properties of building materials. Already during war-time a great deal has been done by the National Standards Laboratory to provide industry with facilities of the nature indicated, and the hope has been freely expressed by industry that these facilities will be continued and extended when hostilities cease.

Collaboration with Fighting Services.

The work of the Laboratory would be conducted in close association with a number of Government Departments and other organizations. It may well be that some of these Departments and, in particular, the Service Departments, will maintain research and developmental laboratories to handle their everyday problems, but there will arise many problems of a more or less fundamental character which it would be the function of the National Standards and Radiophysics Laboratories to investigate and solve. Moreover, it will be a matter of concern at the end of the war that scientific work which will contribute to the efficiency of the fighting Services should be continued. It has been amply demonstrated that the success which can be achieved in war-time is very directly related to ability to attend to the technical requirements of the Services. It is generally agreed that the most effective assistance is obtained from scientists whose normal activities are those of peace-time fundamental research. If called upon suddenly, however, such scientists are unfamiliar with Service problems. It is, therefore, proposed that close liaison should be maintained between the Services and the National Standards and Radiophysics Laboratories, which would always have certain specific problems under investigation for the Services, and which would continuously keep them informed of scientific developments likely to be of concern to them.

Radar Developments.

A conference has already been held in England to discuss the way in which the technical developments in radar may be applied to the control of civil aircraft. Extraordinary developments of a technical character have occurred during the war, and they will lead to entirely new and improved methods for navigating civil aircraft and will enable aircraft to take off and alight on aerodromes in all conditions of weather and at night. These developments have been applied entirely to war-time use. They need skilled investigation and development if they are to be used successfully in peace-time.

The above remarks apply equally to methods for communicating with aircraft. Dangers to civilian flight arise very largely from lack of knowledge of the propagation of radio waves. This would, therefore, form a most important field of study for the Radiophysics Laboratory in the post-war years; it would be a continuation of investigations which have already been commenced.

Physics is the most fundamental of the sciences and has application in both primary and secondary industries. As the basis of all engineering it has led to the development of such branches of technology as electrical, radio-communication, refrigeration and illumination engineering. It deals with such matters as the properties of fibres, fabrics, and soils, and in geophysics with prospecting. In the past, there has been a tendency in Australia to rely to an undue extent on other countries for research, mainly on the grounds that the limited industrial development in this country did not justify the cost of the requisite research facilities. Several of the larger industries had set up laboratories prior to the war, but whilst these have served the useful purpose of solving many immediate practical problems, their scope has been for the most part rather too limited to provide results of major importance. The considerable technological advances which have taken place during the war must be continued and developed, particularly in order to provide employment for a considerable part of the man-power which will be released from the Services. This can only be done successfully by encouraging scientific research, by utilizing our own resources of raw materials, and by ensuring that there is a community of interest in physical research between science and industry.

The National Standards and Radiophysics Laboratories, with a body of competent research physicists and adequate equipment, could provide great assistance to Australian industry by supplying authoritative information and advice on scientific matters, by carrying out investigations on problems arising in industry, and by long-range research on problems of importance to the development of the Commonwealth.

XIII.—AERONAUTICS.

In military aviation the difference between good engineering and bad engineering may mean the survival of a nation or of a political creed. In 1940, the survival of the British Empire depended largely on the Spitfires and Hurricanes in the hands of their heroic and skilful pilots. Thanks to good engineering, the result of enterprising design dependent entirely on sound scientific research, the aircraft did all that their pilots asked of them and the battle for Britain was won. The chief function of the Council's Aeronautical Laboratory is to carry out research and developmental work for the Royal Australian Air Force, the Australian aircraft industry, the Department of Civil Aviation, and other authorities, in connection with the design and testing of new types of aircraft and the improvement of existing types. This is done broadly in the following ways :—

(*a*) By conducting wind tunnel tests on complete models to obtain the general aerodynamic characteristics and to provide data essential for the designer, and on details such as slots, flaps, control surfaces, fairings and cowlings to improve the performance, controllability and safety of the aircraft.

(*b*) By testing power plants and accessories for performance and investigating the conditions under which the greatest efficiency can be achieved.

(*c*) By conducting flight tests in conjunction with the manufacturer or the R.A.A.F., to check such factors as the aerodynamic design, the performance of the power plant installation, the manoeuvrability and the general handling of the aircraft, and the comfort of the crews.

(*d*) By performing mechanical tests on details and representative elements of the structure to provide data for the design of the main air-frame.

(*e*) By conducting tests on complete structural components such as wings, tail-planes, engine mountings, &c., to check the design assumptions, and to establish margins of safety from which can be assessed the possibilities of either reducing the weight or increasing the load.

(*f*) By examining and testing materials of local manufacture with the view to advising on their suitability for specific applications and improving their quality.

(*g*) By developing new materials or manufacturing processes which enable the designer to make more efficient structures or to achieve better performance or more rapid production.

(*h*) By developing special instruments and equipment and thereby improving the numerous materials, accessories and components upon which the satisfactory functioning of an aircraft depends.

The Division is organized into four Sections, viz., Aerodynamics, Engines and Fuels, Structures and Materials, and Instruments. In the following paragraphs some examples are given of the work which has been performed, the difficulties which have been overcome, and the improvements which have been effected.

Aircraft Timbers. Investigations into the suitability of Australian timbers for aircraft, conducted in collaboration with the Forest Products Laboratory, have covered a wide field. Species suitable for use both as solid members and plywood have been found, design data for aircraft structures obtained, and new methods of fabricating timber devised. As an example, wooden belly tanks for fuel—lighter, stronger, and cheaper than the metal tanks previously used—have been successfully developed, thus increasing the range of the aircraft to which they are fitted.

Wind Tunnel. A wind tunnel is a basic item of aeronautical equipment, and one of the first tasks of the Division was to design and put in hand the construction of a modern tunnel of a type suitable for both designers' tests and research. The shell of the tunnel, the aerodynamic balance, and auxiliary instruments were all designed by the staff of the Division and were constructed in Australia. A great many tests have been made to obtain information on the design of new types of aircraft. Numerous armament and parachute tests have also been made. Other miscellaneous tests cover such diverse fields as the cooling of armoured fighting vehicles, the airflow in engine test houses and factories, and the design of plants for the dehydration of food.

Engines and Structures. Considerable improvements have been effected as a result of tests in the Engines and Fuels, and the Structures and Materials Sections. Thus, for one type of aircraft special wings were developed and a new type of engine installation worked out so as to utilize a large part of the energy normally wasted in the engine exhaust. Performance tests of the engine installation of another type extended appreciably the operational range of the aircraft. The monetary value of an increase in the range of a 'plane cannot be directly estimated; but the improvement might well mean that some objective formerly out of range could now be reached, or that some aircraft would be enabled to return to its base in adverse weather conditions when otherwise it and its crew might have been lost.

Japanese Aircraft. Examination and tests have been made of Japanese aircraft, engines, accessories, instruments and other equipment. From these, valuable information has been obtained on the performance of the enemy's aircraft, the strength and quality of the materials used, and the economic position as regards shortages of essential metals, &c. An aluminium alloy of exceptionally high strength was found, and although similar alloys were known in England, they had not been developed for general purposes. This type of alloy is now in production in England and America and promises considerable savings in weight in aircraft structures.

Dust. Considerable trouble has been experienced in the operation of aircraft in Australia owing to the rapid wear of the engines due largely to dust. A special installation to exclude dust has been developed at the Laboratory and a thorough investigation of the fundamentals of the problem is being made.

Reclamation of Cylinders. Investigations into the reclamation of engine cylinders by chrome plating have been conducted, in co-operation with the Munitions Supply Laboratories. The present position is that the life of a cylinder reclaimed by chromium plating is at least equal to that of the original cylinder. The R.A.A.F. is installing plants to salvage cylinders in this way. Reduction of cylinder wear by the exclusion of dust and the reclamation of worn cylinders by chromium plating are two means by which considerable savings can be effected.

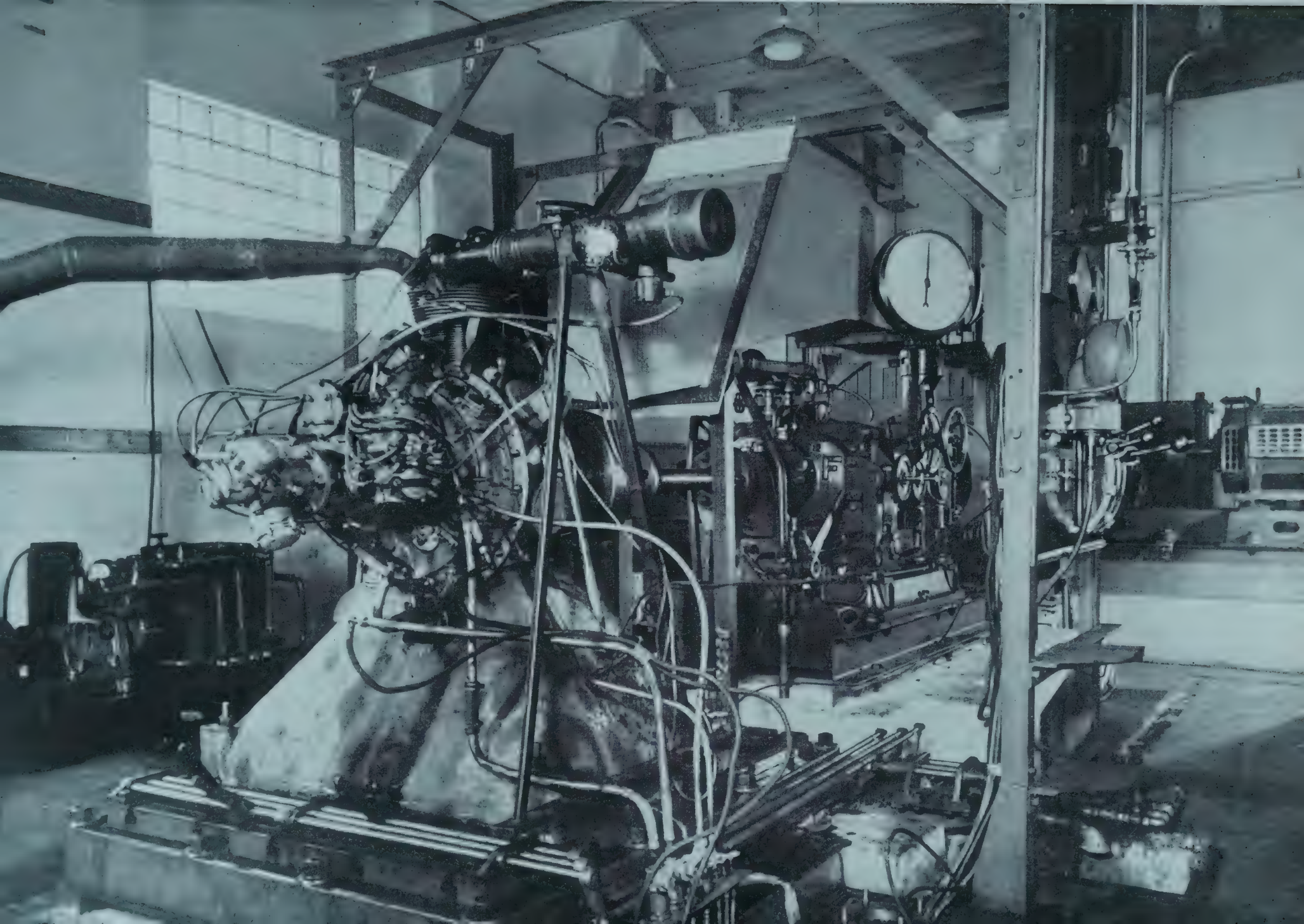
Engine Design. A method has been devised in the Laboratory for producing cylinders for air-cooled aero engines which does not involve expensive forging and machining operations, and which permits of improved design. Cooling fins, instead of being machined out of the solid, can now be furnace brazed to the steel barrel ; also they can be placed closer together and made of high conductivity material, thus enabling a greater power output to be obtained from the cylinder. In the manufacture of a cylinder weighing $7\frac{1}{2}$ lb. it has thus been possible to reduce the scrap of expensive alloy steel from 60 lb. in the old machining method, to $4\frac{1}{2}$ lb. by the new method, not to mention the saving in time and machine tool capacity.

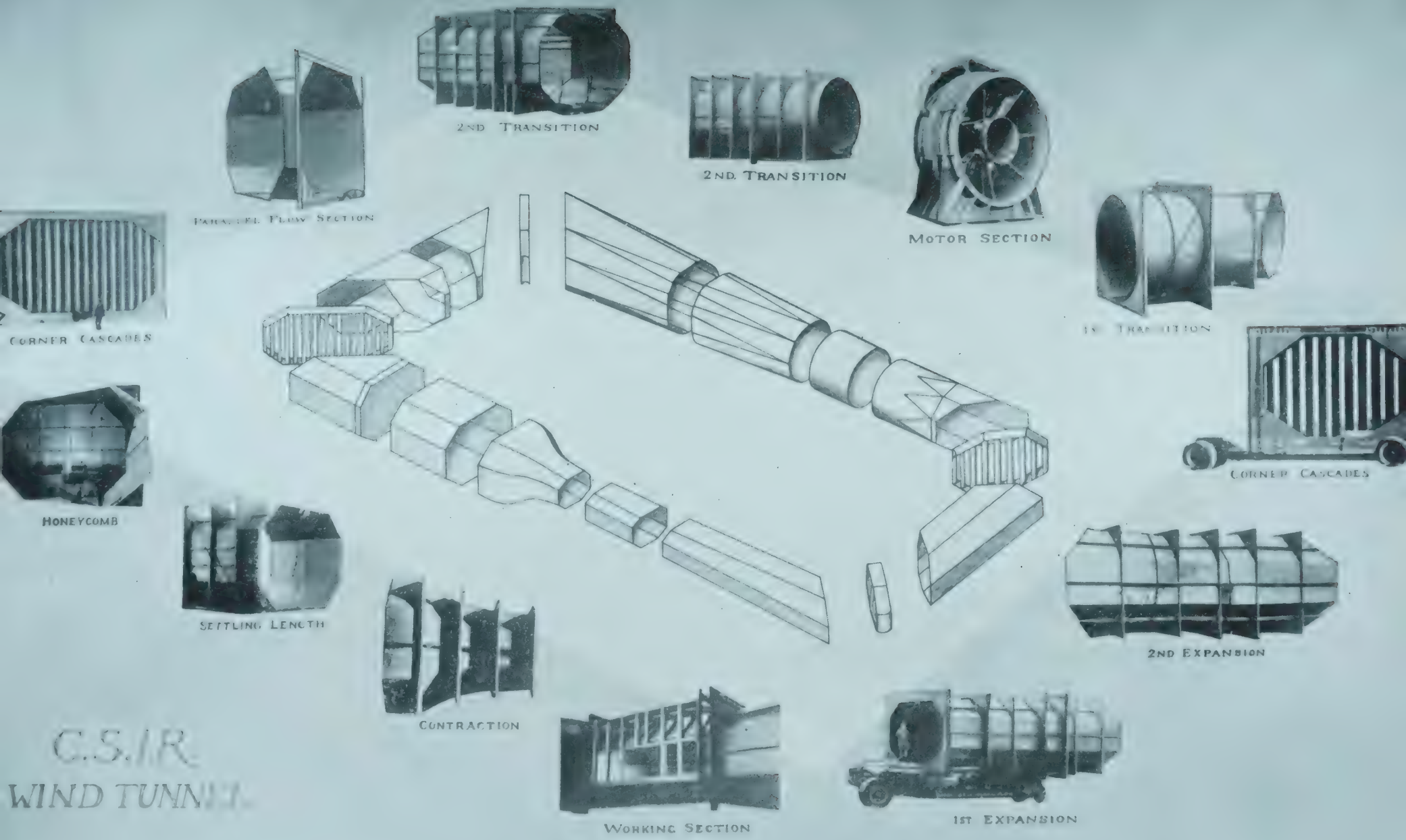
A considerable amount of testing and developmental work has been done on small engines used for Army and Air Force field generator sets. One engine submitted by the Army was an almost hopeless proposition when first tested, but as a result of the Division's work it has, with the co-operation of the manufacturer, been transformed into a successful power unit. Tests of another engine for the Army revealed that it was quite unsuited for operation under the prescribed conditions. The value of these two investigations alone, in terms of a saving of public funds, is very substantial.

Some means of quenching the glow of the exhaust from aircraft required for night operation is necessary so that the 'planes are not easily located by the enemy. The suppression of exhaust glow ordinarily entails a considerable loss of engine power, but the Laboratory has succeeded in devising a very efficient form of flame damper in which the losses are exceptionally small.

Salvage. A service of considerable value has been rendered by the Division in the salvage of aircraft components and materials damaged by corrosion during storage or transport. The causes of the trouble have been traced and appropriate action taken to prevent its recurrence. Large numbers of parts regarded as unserviceable were examined and means found of salvaging them with little or no waste of time or money. This was of vital importance in the early stages of the war against Japan, when it was a crucial matter to maintain the small number of combat aircraft at our disposal in the highest degree of serviceability.

PLATE 13.
Aircraft-engine single-cylinder test plant.





C.S.I.R.
WIND TUNNEL

Parachutes. The dropping of supplies from the air to troops on the ground is an essential operation in modern warfare, particularly in the south-west Pacific area, and some means of reducing the velocity of impact of the packages with the ground is necessary to prevent damage to the contents. The cost of silk parachutes is very high and as silk is in very short supply it must be conserved for personnel parachutes. A hessian parachute was developed by the Laboratory and was found to be very successful ; it is now in large scale production.

Post-war Developments. The post-war activities of the Aeronautical Laboratory will depend to some extent on Governmental policy in relation to the R.A.A.F. and the aircraft industry. It is probably reasonable to assume that there will be an Air Force considerably larger and better equipped than before the war. The future of the aircraft industry which has been built up is uncertain, but probably some part of it will be retained as an insurance against future aggression, apart altogether from civil aviation requirements.

If the Air Force is contracted to well below its present size it will be all the more in need of equipment of the highest possible type so that its effectiveness will be impaired as little as possible by contraction. This would mean that it would have to be aided to the maximum extent by scientific research. The problems which would come to the Laboratory from the post-war R.A.A.F. and the aircraft industry would be much the same as those which are brought along for solution at present. The basic problems in aircraft structures, aerodynamics, engines and instruments are the same for both military and civil requirements, so that what is done for military aviation can ordinarily be used in connection with civil aviation. Plans have already been prepared for great expansion in passenger and freight transport and air mail services in Australia after the war, and they will bring in their train many problems requiring experimental and testing work.

Research work during the war has quite rightly been concentrated on immediate short-range problems, but if the Empire is to retain her position in aviation the research establishments will have to give a prominent place to fundamental long-range research. This means that the Laboratory would take its place in a research scheme on fundamental subjects which would be co-ordinated throughout the British Commonwealth. Apart from this, the future aeronautical work of the Laboratory will consist largely of a continuation and development of the sort of work which it is now doing, but there are many other directions in which the facilities and staff of the Laboratory could render valuable assistance. The science of aerodynamics has applications in many branches of engineering, such as heating and ventilation, design of buildings and structures under wind load, power generation from wind, pump design, and many others, and these applications are likely to increase greatly in the future.

The Laboratory has already done a considerable amount of testing of engines other than aircraft engines ; it has facilities for the investigation of structural materials and metallurgical problems, and these facilities should be available to

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PLATE 14.

Diagrammatic view of the wind tunnel at the Division of Aeronautics.

many phases of engineering outside aeronautics; it could attack problems in applied physics: and, as already mentioned, its aerodynamic work is already becoming applicable to a wide variety of engineering and industrial problems. These are typical examples of investigations other than aeronautical in which the Laboratory could engage after the war. The Laboratory will, of course, continue to have its responsibilities in aeronautical research, and one of these should be specially mentioned as it is likely to assume very great importance in the near future. This is jet propulsion, the importance of which is now established to such an extent that it appears certain to revolutionize both military and civil aviation. Though jet propulsion may not have much effect on the war in Europe now that it is approaching its end, it is not improbable that it will play an important part in the more protracted war against Japan. Theoretical work has already been done at the Laboratory as a basis for future experimental work on the design of compressors and the flow of gases in ducts at very high speeds. The variable pressure high speed wind tunnel is being provided for work in this connection and there will be many problems requiring investigation.

XIV.—INDUSTRIAL CHEMISTRY.

During the past sixty or seventy years, remarkable progress has been made in research in chemistry, and the achievements in the application of the results to industry in the form of many new products, such for example as dyes, pharmaceutical materials, cinema films, and, more recently, synthetic fibres and plastics, have been brought to the attention of every member of the community. The ramifications of the chemical industries are immense, but those which are purely chemical are divided broadly into " heavy " chemicals, which serve largely as raw materials in other branches of chemical industries, and " fine " chemicals, which consist mainly of relatively high priced products. Chemical research has resulted in countless ameliorations of the conditions of life and become a source of wealth and security to those countries in which it has been conducted.

In view, therefore, of the important part played by chemistry in developing the resources, and promoting the prosperity of, any civilized country, it was only natural that when the Government decided to extend the activities of C.S.I.R., plans were formulated for the establishment of a Division of Industrial Chemistry, of which the main objectives are—(*a*) to promote greater technical efficiency in established industries; (*b*) to stimulate the establishment of new industries; (*c*) to encourage the use of raw materials of Australian origin; (*d*) to seek substitutes for imported materials, and (*e*) to find uses for by-products not utilized. As the Division was not established until after the outbreak of war, the problems investigated have been confined almost entirely to those of direct war importance; they have been concerned largely with the development of methods for producing from Australian raw materials products required in the manufacture of munitions and Service equipment. Although it is less than three years since the Division's laboratories were erected and equipped, some notable successes have already been achieved.

Producer Gas Units. One of the first contributions to the war effort resulted from investigations leading to the formulation of specifications for charcoal for producer gas units. Work on foundry sands, including surveys undertaken in five States at the request of the Ministry of Munitions, has been of great assistance to the munitions industry, and its value will be equally great in the post-war period. Work on shrink-proofing of woollen goods required by the Services has led to the introduction into Australia of a process developed by the British Woollen Industries Research Association; another process evolved by the Council's investigators has now reached a stage at which it is ready for commercial exploitation.

Investigations for Services. Numerous investigations for the Services and the aircraft industry include work on equipment for the detection of magnetic mines, prevention of deterioration of transparent plastic aircraft windows and of aircraft cables, cleaning of internal combustion engines, prevention of mould

growth on leather boots, and deterioration of gun-cotton bags. One of these investigations may be specially mentioned. A rapid and efficient method of cleaning pistons of internal combustion engines, particularly of aircraft engines, has been developed; it has been demonstrated on a pilot plant scale and is to be adopted by aircraft maintenance shops with a very substantial saving in manpower.

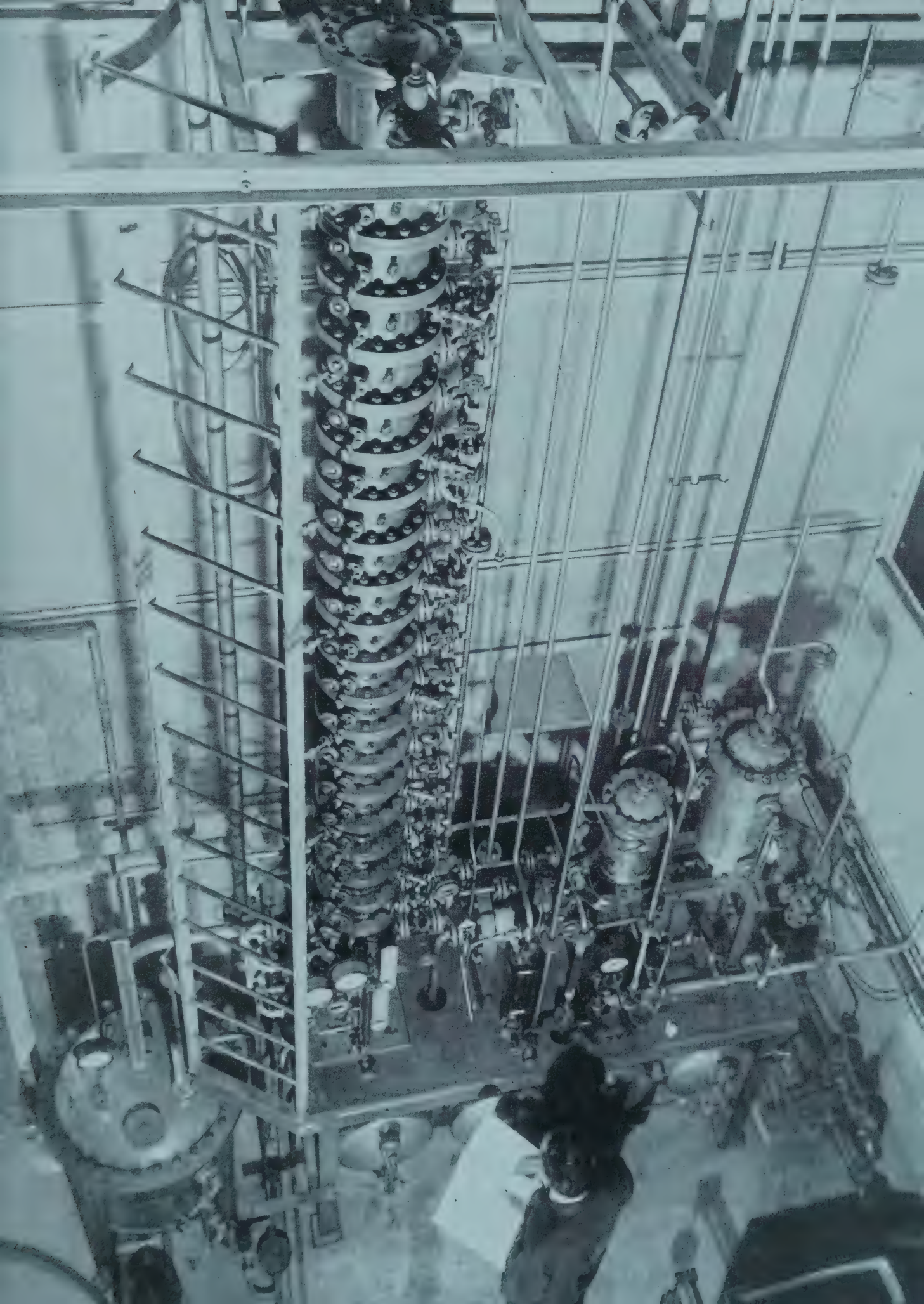
Many other investigations, though not carried out primarily for the Services, have helped them by overcoming problems concerned with munitions production. For example, work on the utilization of the black sand deposits of Australia's eastern shores has been of great value to the war effort. It has shown that these deposits contain millions of tons of valuable minerals and represent, in fact, the most extensive zircon-rutile deposits in the world, though until recently they were exported without treatment. Processes have been developed for producing from them materials for smoke-screens (thus eliminating the necessity for importing large quantities of an expensive product), for an indispensable constituent of radio valves (thus averting a major break-down in the radio valve industry), for the cores of searchlight carbons, and for a polishing powder which will save much time and effort in the production of optical equipment.

Australian Minerals. The utilization of Australian minerals receives constant attention by the Division: it has assisted in developing a process now used on a large scale for the production of potash fertilizers from Western Australian alunite; it has patented a new process and is operating a pilot plant for the recovery of chromium compounds urgently required by the electro-plating, tanning, and paint industries; it has demonstrated that Australian graphite can replace imported graphite with advantage in the production of dry cells, which are required in huge quantities by the Services for communication systems; and it is working on lithium and beryllium minerals with a view to their exploitation for important war-time needs.

New Products. The war revealed that one of Australia's chief industrial deficiencies was the lack of an organic chemical industry upon which important sections of the munitions industry must be based, and certain of the Division's activities have been directed towards overcoming this deficiency. The Division's experimental work has stimulated the interest of several Australian companies in the production of ethylene from alcohol and of furfural from waste agricultural products, both used in the plastics and related industries. The Division is at work on a process for producing much needed waxes from waste organic acids; it has determined the basic data from which the gas industry can design plant for producing organic chemicals from tar oils of low value; it has worked out methods for preparing synthetic rat poisons required by the Army and chemicals for essential drug production; it has developed synthetic resin adhesives necessary for the production of improved wood for propeller blades and

PLATE 15.

Experimental distillation unit at the Division of Industrial Chemistry, installed for the study of a wide range of distillation problems. This unit is at present being used to obtain information on the distillation of solutions of furfural, which is a raw material for the manufacture of synthetic resins.



other purposes, and has assisted the plastics and adhesives industries in other ways. Mannitol, a chemical required for radio condensers and having several other important uses, has been produced from a manna exuded from the sandalwood trees of the Mallee, and the possibility is being explored of establishing a small but profitable industry.

Cement. Supported financially by cement manufacturers, work is in progress on certain important problems concerned with methods of producing and utilizing cement. It has already been shown that in certain areas difficulties will arise from the cracking of concrete structures unless special care is taken along clearly specified lines, and cognizance of this is being taken by the appropriate authorities. There is little doubt that this work has already averted serious economic losses.

Fellmongering. In following traditional methods, the fellmongering industry in Australia inevitably loses many skins and much of the wool recovered is not of the highest quality. Investigations which are being conducted give promise of improvements which will decrease substantially the losses of skins, improve the quality of the recovered wool, use fewer men, and make conditions of employment more congenial.

Wide Scope of Work. The work of the Division covers many aspects of chemistry, from industrial bacteriology to physical metallurgy. Advisory work is a major function of the Division, the most extensive advisory services being concerned with the production of aluminium, the utilization of tin and recovery of tin from tinplate scrap, the synthesis of organic chemicals, and the manufacture of synthetic rubber. Arising from the demand for this advisory work, many investigations have been undertaken : thus the suitability of Gippsland bauxite and the synthesis of cryolite from Australian minerals have been studied in connection with the proposed aluminium industry ; a flotation process, now patented, has been developed for the concentration of tin from its ores; substitute solders have been developed ; and a study is being made of the production from wheat of butadiene, a starting point for a synthetic rubber. The valuable drug ergot has been separated from the rye grain, with which it is associated, by a novel and efficient process akin to that used in concentrating minerals, and the whole of the 1943 crop was treated in that way. Much work as also been done in connection with the development of substitute containers to conserve tinplate in the packing of foodstuffs.

The development and indeed the survival of Australia's secondary industries demand continuous technical improvements, otherwise the increased attention now being given to scientific research and development in other countries may enable these countries to undersell our manufacturers even in our own markets. Much of this work should be undertaken by individual companies, but there are many problems common to a number of companies or to several industries that can be most effectively studied by the Division.

PLATE 16.

Pilot plant for the production of chromic anhydride from chromite ore. In the foreground are the electrolytic cells for the oxidation of chromic sulphate to chromic acid. Chromium compounds are required for the paint, tanning, and electroplating industries.

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The industrial chemist helps primary industry as well as secondary. Thus the work to which reference has already been made has helped the woollen industry, the dairy industry, and the foodstuffs industry; it has stimulated interest in mining and treatment of many minerals; it aims to create uses for agricultural products, and it should lead to better utilization of coal. Much remains to be done in all these fields, but it is important to observe that returns from the results of research are recurrent, and that the benefits to industry continue long after the investigator has turned to new problems.

Post-war Developments. The Division has prepared comprehensive plans for post-war research. It proposes to undertake further work in the important field of utilization of non-metallic minerals, in which Australia lags far behind more industrialized nations. The lag is not caused by limited resources of the appropriate crude minerals, but by the present inability of the cognate industries to obtain locally-prepared intermediates derived from these minerals. The object of the research will be to encourage the local processing and use of such minerals which are, at present, largely exported in a crude state and frequently re-imported in a prepared form. This applies to such minerals as zircon and rutile, of which Australia possesses unique deposits. Many other examples, particularly the varied materials used in ceramic manufactures, might be cited. It is proposed to undertake research work to assist the ceramic industry, which has an annual value of £5,000,000 and employs 10,000 men and women. It is known that this industry, which consists of relatively small units unable to undertake extensive research work themselves, would welcome the Division's help in such diverse fields as the manufacture of bricks and refractories, insulators and drainage pipes, ornaments and dinner ware.

The extraction of gold from many of its ores offers difficulties that can be solved only by the chemist and the metallurgist working in close co-operation. Metallurgists who have been consulted consider that fundamental chemical work is needed on methods of assaying, on the cyanidation process for recovery of gold, on refractory ores that are not amenable to conventional methods of treatment, on the flotation and roasting of ores, and on the recovery of such elements as sulphur and tellurium from materials with which gold is often associated. This work would be of greatest value to Western Australia, but many of the problems are common to all gold-mining areas, and the Division plans to undertake work on them as opportunity arises.

As Australia's hydro-electric resources are developed there will be greater need for electrochemical and electro-metallurgical research. Direct help could be given to the electroplating industry; the claim that the standard of galvanized products has deteriorated in recent years should be investigated and, if substantiated, improvements devised; and fundamental studies should be initiated with a view to assisting zinc, aluminium and copper producers.

In the field of organic chemistry, further studies are needed of the resins, essential oils, alkaloids and tannins from the shrubs and trees of Australia and neighbouring territories. Synthesis of new organic compounds for use as fungicides and insecticides and in medicine is desirable, and also for use in the

flotation of minerals, in which field the Division has established a world-wide reputation. Development of the plastics industry utilizing Australian materials presents special problems. Effective utilization of our resources of black and brown coal with recovery and utilization of the many valuable by-products will require intensive researches and modern pilot plant. It is impossible at this stage to predict whether Australia will undertake production of any types of synthetic rubber, but, if it does, organic chemists would have a notable opportunity to serve their country.

The paint and varnish industry in Australia has 2,000 employees, and the annual value of its products is £4,000,000, though in pre-war years £1,000,000 worth of goods were imported. The discovery of a drying oil of Australian origin to replace imported linseed oil would be very valuable. The leather industry, like the woollen industry, sells much of its production in world markets and faces intense competition from synthetic materials. Like wool, therefore, leather needs scientific research as an active ally.

Wool may be regarded as a raw material from which better fibres could be built by the chemist and from which he may make products not now known. He must shrinkproof it, mothproof it, creaseproof it, and shineproof it ; he must give it a glossy or a dull surface at will ; he must learn to dye it more attractively and cheaply ; and he must regard it as a protein from which may be made more valuable products. He must develop methods of recovery of wool wax, and make chemicals and drugs from its many constituents, some of which still require identification. He must improve present methods of carbonizing and scouring, and give still more assistance to the fellmonger.

It is obvious that there is a vast and in fact practically unlimited field of research demanding attention in connection with Australia's chemical industries. During war-time urgent investigations with immediate prospects of utilization of the results have naturally claimed precedence, but when the war ends it is important that work of a more fundamental character should be undertaken. It may be impracticable for C.S.I.R. to enter all the proposed fields of chemical research in the near future, but it should certainly do so within the next five years or so.

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XV.—DAIRY PRODUCTS.

The importance to Australia of the dairying industry does not require emphasis and before the war the Council had taken preliminary steps for the investigation of problems affecting dairy products. The war gave rise to some urgent problems of dairy manufacture, owing partly to the increased demand and to the special conditions which had to be met, e.g., with respect to supplies which would stand up to tropical conditions and to shortage of refrigerated shipping space. A Dairy Research Section was accordingly established in 1940. Its work was first centred at the School of Dairy Technology, Werribee, where facilities were made available by the Victorian Department of Agriculture, but early in 1942 laboratory accommodation was provided for the Section at the Council's Industrial Chemistry Laboratory at Fishermen's Bend, Melbourne.

Butter Boxes. Before the war a very serious difficulty arose owing to the curtailment of supplies of New Zealand white pine, which had been used almost exclusively for the manufacture of butter boxes. It was found that boxes made of certain Australian timbers imparted a marked taint to the butter, attributable to volatile oils in the timbers. Investigations were accordingly undertaken and a satisfactory process was found for eliminating the taint from boxes made of Australian hoop pine by spraying them with a solution of casein (a by-product of the dairying industry) and formalin. This was of very considerable importance, as it enabled Australia to replace expensive imported timbers with local timbers and enhanced the price obtained for butter by eliminating the objectionable taint. All butter exported from Australia during the last seven years has been packed in boxes treated by this process. During that period over 40,000,000 boxes, holding over 1,000,000 tons of butter, have been treated and wood taint is now a thing of the past. The result of this work was the complete abolition of a trouble which caused considerable financial loss to the dairying industry.

Low-grade Butter. Large quantities of low-grade butter had accumulated in Australian cold stores owing to the fact that it could not be exported on account of shortage of refrigerated shipping space. Work was accordingly initiated to discover a process whereby pure butterfat could be produced from the low-grade butter and exported without refrigeration. A suitable process was evolved and considerable quantities of butterfat have been exported at a satisfactory price, thus obviating serious losses of low-grade butter which otherwise would not have been sold.

Tropical Spread. Another urgent problem arose from the fact that butter melts and deteriorates rapidly under tropical conditions. Investigations resulted in the production of "tropical butterfat spread", which has a melting point 20° F. higher than that of butter and which is not subject to bacterial deterioration. Large quantities of this have been supplied to the U.S. and Australian Services. In the first eighteen months of production nearly 8,000,000 lb., valued at £900,000, were manufactured.

Butterfat. The keeping quality of butter in cold storage is of great importance and is dependent on a number of complex factors, which have been investigated. As a result conditions of manufacture required to ensure maximum keeping quality have been defined. The causes of loss of butterfat in churning have been studied and methods have been evolved for reducing them to a minimum. For export purposes it is important that Australian butter should be of high uniform grade; variations in the properties of butterfat have been studied and the results will be of value in enabling a more uniform standard to be produced throughout the whole continent. A successful method has been developed for compressing milk powder into blocks, resulting in a substantial saving in both shipping space and containers, whilst at the same time improving the keeping quality of the powder. Improvements have also been effected in the keeping quality of milk powders under tropical conditions.

Post-war Developments. The dairying industry must meet increased competition after the war and the importance of research to assist the industry and to improve its products is apparent. As Australia becomes more industrialized and the population increases, greater emphasis must be placed on the better utilization of milk and milk products. Butter utilizes only one-third, and cheese two-thirds, but dried milk all of the nutritive value of milk. The present method of distributing fluid milk in cities is most inefficient from every point of view—labour, material, and the health of the community. Research is required on dried milk and its reconstitution, so that ultimately it may be the equal in every respect of the best liquid milk.

Much of the cheese made in Australia is of poor quality, and the post-war period would be an appropriate time to undertake research which would enable sound advice to be given on a number of problems affecting cheese manufacture. Though cheese is a most valuable foodstuff, its consumption in Australia is low. More varieties should be provided if consumption is to increase and little is known in Australia about their manufacture. Research on improved methods of butter manufacture and "modified" butters will be necessary if butter is to face the almost certain increased competition from margarine. The investigations already conducted into the production of "modified" butters for use in the tropics should be continued so as to encourage their use in places where ordinary butter is not suitable and thus to increase production and exports. Increased industrialization in Australia has already created a larger demand for dairy by-products such as casein, lactose and lactic acid, and this demand must increase further in the future. It is, therefore, important that research on the manufacture and utilization of these products should be undertaken.

The valuable results achieved by the Dairy Research Section during the brief period for which it has been in existence show that further research cannot fail to have most beneficial results. In comparison with other countries with large dairying industries Australia has so far provided only small facilities for research. If the Australian dairy industry is to adapt itself to meet post-war conditions efficiently there must be a considerable increase in research activities.

XVI.—LUBRICANTS AND BEARINGS.

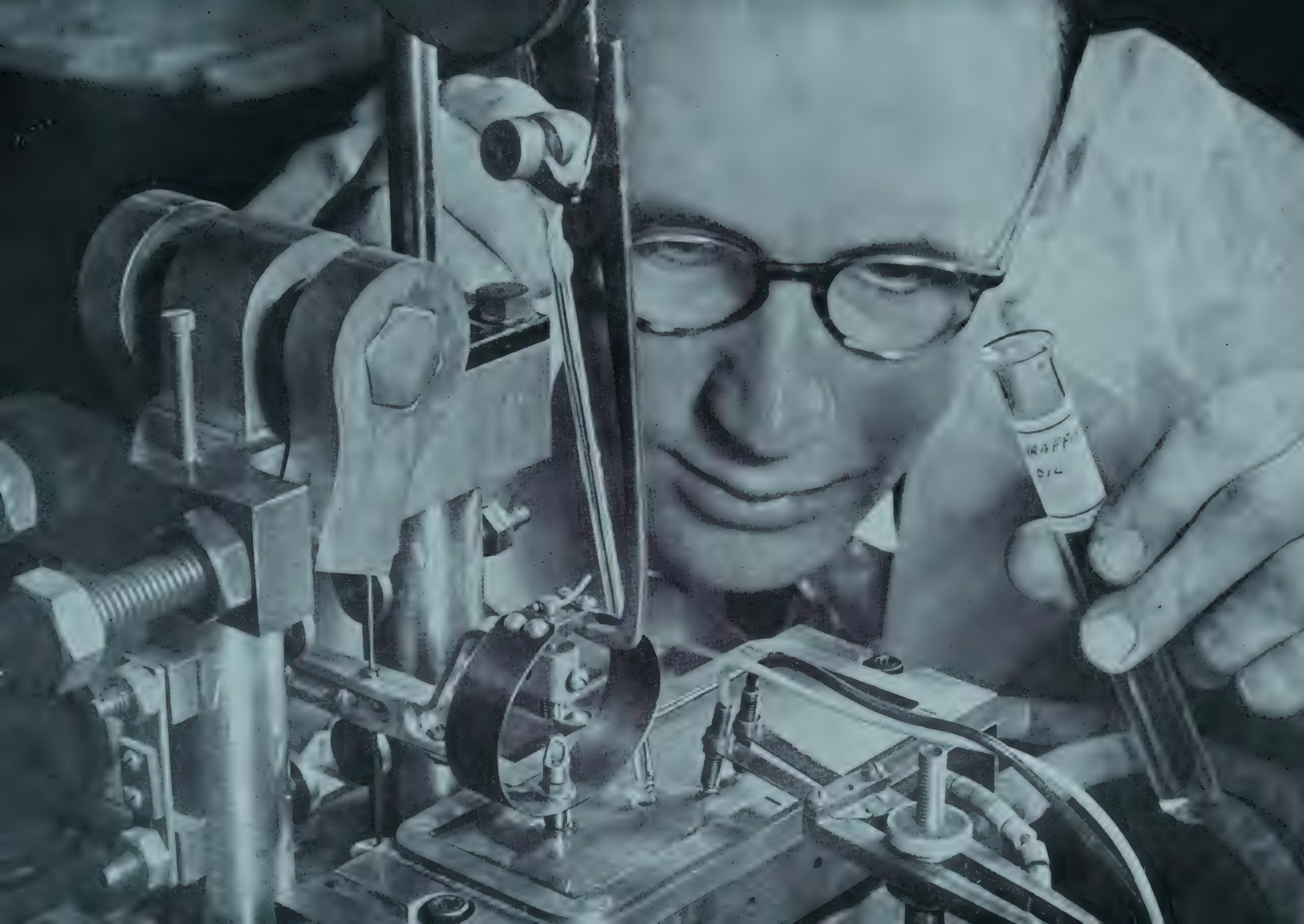
Early in 1940, C.S.I.R. established a Lubricants and Bearings Section for the purpose of investigating problems associated with friction, lubrication, bearings, and wear. This action was taken partly as a result of requests for authoritative advice on a number of serious difficulties experienced by the Services and by certain manufacturing industries which had been established in connection with the war effort, particularly the aircraft industry. It was obvious that there was an important field of work which the Council should investigate in order to develop and apply to the solution of these problems results of fundamental work already carried out in England. This work has a direct and important association with the lubrication of metals under difficult conditions of high temperature, as, for example, in the case of piston rings and bearings of aircraft and other high speed engines; it also provides a valuable guide as to the selection of correct bearing metals for special purposes and the prevention of corrosion, scoring and seizure of bearings. Accommodation for the new Section was provided by the University of Melbourne.

The work of the Section was planned in two main directions; the first a basic attack on problems of friction, lubrication, wear and associated phenomena, and the second the application of methods and results to the practical problems of the services and industry. During the war it has been necessary to devote attention primarily to the solution of problems for the Services. These have been numerous and varied; particulars of some of those which are of more general interest are given in the following paragraphs.

Boundary Lubrication. Under high loads and low speeds, lubricated surfaces are often separated only by a very thin film of lubricant of molecular dimensions. This state is called boundary lubrication; the friction is relatively high and it is during this condition that most of the wear takes place and that seizure is more likely to occur. Apparatus and methods have accordingly been developed by the Section for studying the mechanism of boundary lubrication. This work has yielded valuable information on the action of various lubricants and the Section has been successful in developing fluids for such purposes as the drawing and pressing of metals, cutting oils and extreme pressure lubricants. These fluids have largely replaced imported products and are now widely used in Australia for the drawing of shell and bomb cases and in the machining of aircraft engines.

PLATE 17.

Stick-slip apparatus for analysing the friction between sliding surfaces in the presence and in the absence of lubricants, at room temperatures and at elevated temperatures. In this photograph the lubricating properties of paraffin oil on steel surfaces are being investigated as the surfaces are warmed.



Aircraft Engines. New processes have been developed for measuring the finish and damage of rubbing surfaces and for studying the breakdown of lubricating films between the piston rings and cylinder walls of engines. A study of the physical processes occurring during wear has led to the adoption of materials giving reduced wear in aircraft engines, to a selection of brake lining materials for military vehicles operating under sandy conditions, and to the solution of other practical problems.

Apart from a number of basic investigations of the theory of bearing alloys, the Section has worked out techniques for the manufacture of all the major aircraft bearings used in Australia. The production of cast copper-lead and electroplated silver-lead bearings is now firmly established and Australia has thus become largely independent of imported bearings.

Explosives. An investigation has been made into the mechanism of detonation of liquid and gelatinous explosives by friction and impact. The results showed that if certain conditions are fulfilled, even the supposedly insensitive explosives can be detonated by minute blows. Apart from its theoretical interest, the results have important practical applications in connection with the safe handling of explosives, the prevention of accidents during manufacture, and the development of detonators in which the use of primary explosives may be avoided. Details of this work have been communicated in confidence to authorities in England and the United States of America, where they have aroused very great interest and where special conferences attended by an officer of the Section have been held to consider developments and practical applications.

Special thickened fuels for flame-throwers for use in the Pacific area have been developed for the Department of the Army. These are now in large-scale production. For security reasons particulars cannot be disclosed.

Muzzle Velocities. In investigating the mechanism of friction it became necessary to study extremely rapid transient phenomena which occur for only a very short time interval of the order of millionths of a second. The results of this work have been applied to the measurement of muzzle velocities of shells by photo-electrical methods, and highly specialized equipment has been developed for improving the accuracy of gun-fire. This equipment has been accepted by the Departments of the Navy and the Army and the British Admiralty, and is now being made in Australia. Work has also been done on the wear of gun barrels, the penetration of fragments, and the friction of the driving bands of shells.

Post-war Developments. With the development of secondary industries the demands on the Section are likely to be heavy. Close contact has already been established with a number of major industrial concerns. Most of the problems on which the Section has been working during the war concern production and the general wear and performance of machinery; problems of this sort will continue

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PLATE 18.

Electrical examination of lubrication in the cylinder of an engine. The amount of metallic contact occurring through the oil film between the piston ring and the cylinder wall is shown on the cathode ray trace.

to be of importance in peace-time and the post-war activities of the Section will not require any major change in its programme of work. Certain work for the Services will continue, but the pressure of work on immediate problems will be relieved, so that more time will be devoted to problems connected with the development of Australian industries and with longer range basic research. The war-time work of the Section has already resulted in applications which were quite unforeseen and which are of very considerable interest and importance, e.g., in connection with detonators and gun-fire. Such developments are, of course, only to be expected as a result of the acquisition of new knowledge. It is reasonable to assume that after the war the manufacture in Australia of internal combustion engines for various purposes, including even motor-car engines, will be developed. Not infrequently the limiting factor in the design and successful operation of machinery is determined by the lubrication and wear of the moving parts. Australia imports its lubricating oil and it is, therefore, all the more important that it should use it as economically as possible. Work has been carried out by the Section on the reclamation of used oils, and on the selection of suitable oils for various purposes, and this work will be extended. It is possible that after the war we may have access to new sources of oil supply in the Pacific and we should be technically equipped to deal with them.

XVII.—MINING.

The importance of investigations for the development of Australia's mining industry and the utilization of our mineral resources has not been overlooked by C.S.I.R. In the section relating to Industrial Chemistry, brief reference has been made to work on the processing and utilization of certain non-metallic minerals. Since 1927, investigations have been conducted by the Council in the field of what is known as mineragraphy ; in addition, a programme of ore-dressing research is carried out in co-operation with the Kalgoorlie School of Mines, the South Australian School of Mines and Industries, and the Metallurgical School of the University of Melbourne.

Every ore body has its own special problems which can be more clearly defined and more directly attacked when information is available concerning the precise mineral content of the deposit. Ore-dressing procedure is based upon the nature of the valuable minerals, the size of the individual crystals, and the nature of their association with the other minerals present. The aim of mineragraphic investigation is to supply this basic information, and this has been done in the past for ores that have been subjected to experimental testing in the Council's ore dressing laboratories. It has also been applied to treatment processes in operating mills where the progress of any particular mineral can be followed through all stages and the nature of the impurities in the concentrates or the losses in the final residues can be determined. Such information gives an insight into the cause of such losses and the possibility of remedial measures.

Mineragraphy. The mineragraphic methods consist of the microscopic examination by reflected light of polished surfaces of ores which may have to be etched with chemicals to bring out their crystalline structures. By means of this special technique the precise nature of the different minerals present and the size of the particles can be determined. The technique is highly specialized and requires considerable experience, so that it is only rarely that it can be applied by the staffs of operating mines.

Samples of ores and metallurgical products from a large number of sources have been received and examined during the course of the mineragraphic work. To cite but a few examples : the gold content of chlorinated residues from a mine in Queensland was determined and found to be largely due to fragments of gold contained in roasted particles and thus inaccessible to direct cyanidation. Tin ore from a New South Wales mine was examined ; the silver-bearing mineral was found to be so intimately associated with stannite and galena that its separation from either by the flotation method would be impossible. The mineral

composition of a series of samples from a gold mine in Victoria was determined, as well as the mineral content and the gold in a flotation concentrate: the information thus obtained was used in experimental ore-dressing tests which led to successful methods of treatment.

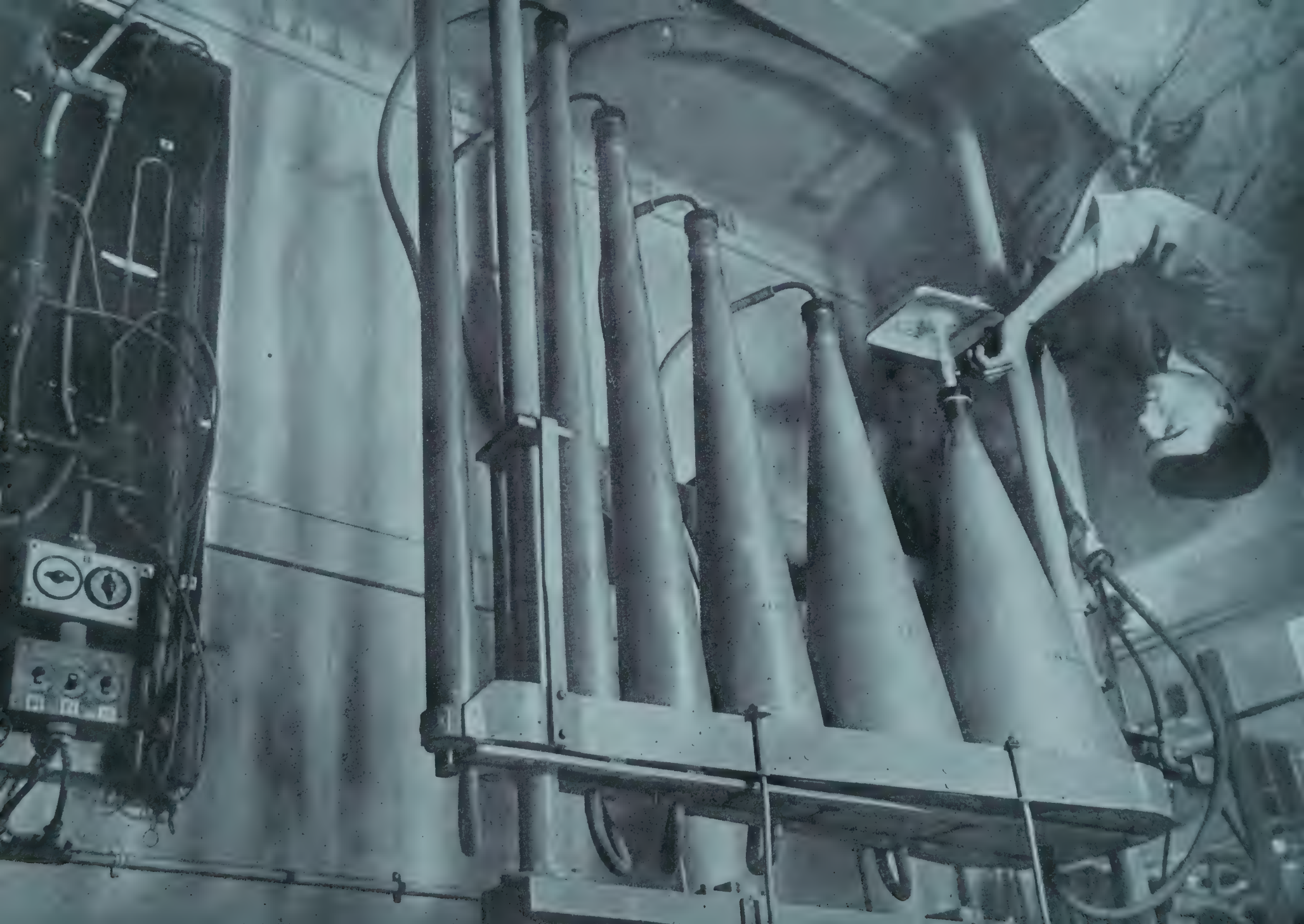
Base Metals. Before the war, the mineragraphic work was concerned mainly with gold ores and their mill products: only about 10 per cent. of the work related to the base metals—tin, tungsten, molybdenum, &c. The advent of war and the curtailment of gold mining stimulated the search for ores of minor metals and created many problems. Investigations relating to lead, zinc and copper ores have remained fairly constant in number during the war as compared with the pre-war period.

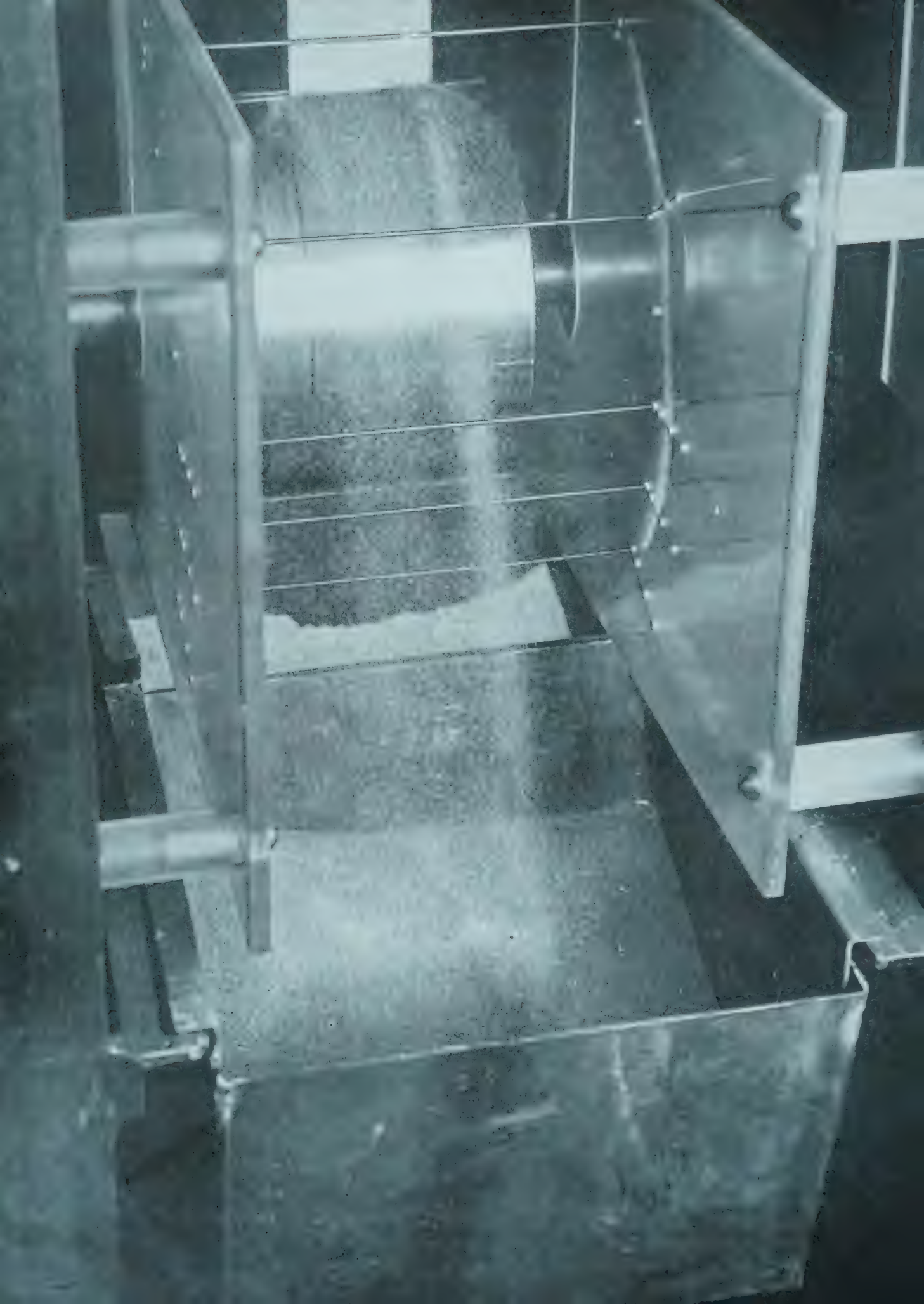
Ore Dressing. In 1934 funds were provided for ore dressing work in the belief that unworked deposits could be brought into profitable production if advice were available to help in determining the most suitable method of treating each type and class of ore. It is open to any leaseholder to request that his ore be tested: the only condition is that the Council should be assured that the samples are representative of sufficiently large bodies of ore to warrant the examination. The actual testing of the samples, covering such operations as grinding, cyaniding, and flotation, is carried out in the laboratories of one or other of the three co-operating bodies already mentioned. The objective is to obviate the losses of capital which are so often involved in the exploitation of our mineral resources.

War Problems. As in the case of the mineragraphic work, most of the ore dressing investigations were confined originally to gold ores. During the war, attention has been diverted from gold mining to problems connected with the economic and strategic base metal and non-metallic minerals. Much work has been done on samples of ore submitted by the Minerals Committee of the Department of Supply and Shipping. Extensive investigations on King Island scheelite ore have formed the basis for the design and erection of a large treatment plant: this work is of importance in connection with much wanted supplies of tungsten for special steels and for carbide-tipped cutting tools. The technical assistance provided in South Australia has enabled high-grade graphite concentrates, urgently needed for munition work, to be produced from a local deposit. Other work has concerned the recovery of antimony and tungsten from dumps, zinc from galvanizing residues, and minerals from beach sands; the use of untreated, finely ground phosphate rock as a fertilizer; the flotation of copper ores, and many other problems.

PLATE 19.

Haultain Infrasizer used in mineragraphic work for sizing finely-ground ore. The sample is placed in the smallest tube and compressed air is passed through the control board at the right.





Post-war Developments. During the war the lack of transport has helped to turn the attention of manufacturers to Australian raw mineral products, but after the war competition from other sources must be met and the quality of the domestic article must be raised to the highest possible pitch to retain the home market. Both Commonwealth and State Governments are called upon from time to time to assist financially the development of mining properties and, when such aid is granted, the existence of ore-dressing laboratories is essential to prevent wasteful expenditure. Large mining corporations have their own laboratories, but smaller concerns must rely on the services of a central laboratory if they are to play an efficient part in the development of the country's resources and the conservation of its capital. Projects planned by the laboratories for the immediate future and for the post-war period include the beneficiation of manganese ores for the manufacture of dry cells, the development of deposits of china clay, and the investigation of certain general problems of interest both technically and financially to the whole mining industry and, therefore, to the Commonwealth.

PLATE 20.

Electrostatic separation of zircon from rutile in the ore-dressing laboratory. The powdered minerals are poured through the chute at the top of the picture on to a positively-charged earthed roller. In front of it are negatively-charged electrodes which attract the particles of one mineral away from the roller, allowing them to fall into the bin in the foreground. Particles of the other mineral cling to the roller until brushed off.

XVIII.—SCIENTIFIC RESEARCH AND POST-WAR RECONSTRUCTION.

Although the review of the Council's work given in the preceding pages shows that much has been accomplished, the key note of the future is clear. In each Division and Section the many problems requiring elucidation afford a vivid impression of how much needs to be done in order to prepare for a better and brighter future.

Research and National Prosperity.

Broadly it may be taken that the case for research for reasons of national prosperity and security is self-evident. Discovery and invention have been the essential factors in laying the foundations for the material progress and welfare of the civilized world, and the importance of research in national economy now receives universal assent. In Australia as well as in other countries attention is being given to plans for the post-war period. Large research schemes of post-war significance are already afoot in England, and America is active in the same field. In order to meet inevitable competition Australia must be prepared to maintain a high level of production, to utilize to a much greater extent than in the past her own raw materials, to increase the efficiency of existing industries and develop new ones, and to mobilize her resources by collaboration between her scientific, technical and productive agencies.

All this can be done if the necessary ways and means are provided. It is impossible to generalize in regard to the future requirements of the Council's Divisions and Sections. In some it may be possible to carry on effectively with little or no additional expenditure after the war, when the depleted staffs are reinforced by the return of men who have enlisted or who have been seconded for war duties and when the pressure of work arising out of the war lightens. In others, to tackle even a proportion of the problems to which attention has been drawn, more accommodation, more equipment and more qualified men will be needed. Moreover, there are certain major branches of work which call for attention, but which are so far untouched. For example, building research is of direct concern to every member of the community and though it will be practicable for some time to carry on by utilizing existing facilities either within C.S.I.R. laboratories or in other institutions, before long special accommodation and facilities will be required. Again, metallurgical research is of outstanding importance in Australia. While metallurgy is one of the oldest of the technical arts, the science associated with it is of modern growth: in no other branch of

science have there been more important developments in recent years or is there greater promise of future growth. Linen flax has been grown in Australia for many years, but until recently the industry languished. As a result of research by C.S.I.R. some of the most urgent problems have been overcome and it is obvious that the industry should be maintained after the war. To enable this to be done, continued investigations are necessary and for that purpose additional accommodation and facilities will be required. Again, much has recently been written and said about the danger confronting Australia's wool industry through the competition of synthetic fibres, and it is difficult to see how this competition can be met except by scientific research on the biological side to improve the quality and yield of wool and reduce the cost of production, and on the physical and chemical side to find new uses for wool and to overcome the disadvantages from which it suffers. If work on these problems is to be undertaken effectively considerable expenditure will be required.

The hope for the future lies in a well-balanced structure in which the great branches of industry, agriculture, mining and manufactures, from which all our wealth is derived, may contribute to progress, increased employment, and prosperity. For these reasons, the steps already taken by C.S.I.R. to carry out investigations into the many problems of our agricultural and pastoral industries and to inaugurate research into manufacturing industrial problems, should be actively pursued. To enable this to be done additional accommodation, equipment and staff will be required.

Achievements of C.S.I.R.

It may be unfortunate that the results of the Council's achievements cannot generally be expressed in terms of money, but experience not only in Australia but also in other countries has shown that scientific research is, in fact, a most profitable investment. The curtailment of expenditure on an important scientific investigation may give a sense of economy and may appear for the time being to cut down expenditure, but it will not help in the long run to balance the budget or to lift the tax burden. The net effect is hardship on the farmer, the manufacturer, or the consumer in later years when the much greater tax of unaccomplished scientific effort will be felt. From some points of view it may be regretted that the profits from the work of C.S.I.R. cannot flow back directly to the country's revenue; they are made by the Australian people as a whole. This is of course appropriate, for the business of the Government is not to make money but to undertake functions which benefit the people.

Though the direct monetary value of the achievements of C.S.I.R. cannot be stated, there is no doubt that it must amount to many millions of pounds. A very great deal has been done to assist in the war effort, and the value of the contributions thus made to national security is, of course, incapable of expression in terms of money. However, the review which has been given of the results of the Council's work speaks for itself and is sufficiently impressive. The days of progress through the slow and half-unconscious accumulation of traditional knowledge are long past. The only way in which swift and assured progress can be made is by experiment and observation by well qualified men, and plans for reconstruction can be successful only if they are based on the firm foundations of knowledge and experience.

Pure Research. Attention has been directed to many problems in applied science on which the efficiency of Australia's development must largely depend: reference has also been made to certain major lines of investigation for which new Divisions or Sections should be established. What has so far been said relates to the application of scientific knowledge to industrial problems. It must, however, be realized that without pure research, leading to the acquisition of new knowledge, there is a definite limit to the progress which can be made. Pure science must come first in point of time. When new knowledge is acquired, no one can say that it will be useful for any particular purpose. All one can say with certainty is that it will be useful some day.

The distinction between pure and applied science is, however, to a large extent vague and artificial: it is true that the objective of the worker in pure science is to find new knowledge, while that of his fellow in applied science is to utilize it, but it not infrequently happens that a scientific industrial problem cannot be solved simply by the application of existing knowledge and that the only hope of success lies in an approach whereby fundamental knowledge of the properties or composition of the particular materials or of the phenomena concerned can be acquired.

As pointed out by the British Parliamentary and Scientific Committee in 1943 in its report on Scientific Research and the Universities in Post-War Britain, applied science cannot live on the fundamental discoveries of past generations; unless fresh discoveries are made it dies of inanition. Pure research cannot be confined to the Universities, which are already overloaded with teaching duties. Government research organizations, such as C.S.I.R., have also an essential part to play. It is common knowledge that many discoveries in the field of pure science regarded originally as solely of academic interest have very rapidly become of prime importance as the foundations of new industries.

Conclusion. The conclusion to be drawn from this review of progress and preview of problems to be tackled is that in order to ensure the material prosperity of the Commonwealth—or if regarded only from the point of view of a good national investment—scientific research should receive increased encouragement and support. Recent events, such as the development of radar and jet propulsion and the remarkable progress made in Australia in the adaptation of our industrial efforts to meet war requirements, have led to a more general appreciation of the dependence of our national welfare and even our national security on scientific research. It is, therefore, reasonable to expect that there will be a whole-hearted recognition by the Commonwealth and State Governments, as well as by industrial establishments and individuals, of the supreme importance of utilizing and developing in the fullest measure Australia's scientific resources, not only so far as C.S.I.R. is concerned, but also in other Government research organizations, in our Universities and Technical Colleges, and in industry generally.

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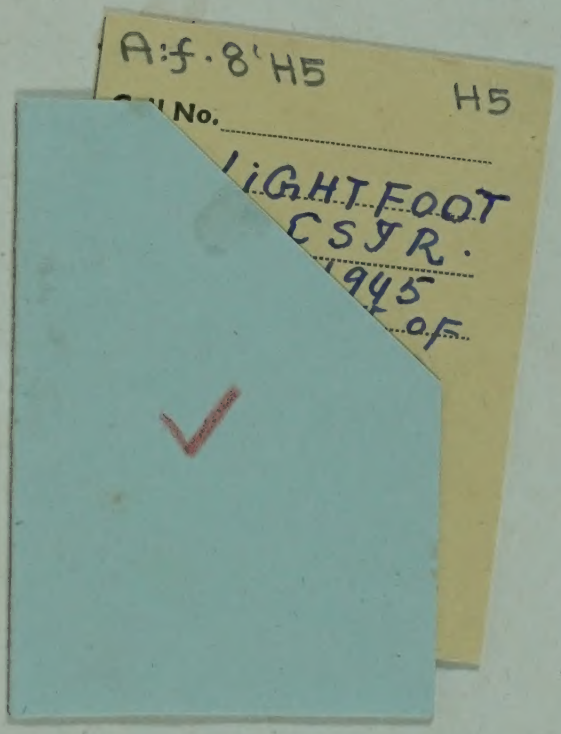
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